DESIGN, IMPLEMENTATION, AND ASSESSMENT OF MATHEMATICAL MODELING OF AGRICULTURALLY BASED STEM ACTIVITIES AT THE ELEMENTARY GRADE LEVEL

by

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A Dissertation

Submitted to the Faculty of Purdue University

In Partial Fulfillment of the Requirements for the degree of

Doctor of Philosophy

Department of Agricultural Sciences Education and Communication

West Lafayette, Indiana

August 2021

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To my younger self.

A girl who remained determined, dedicated, and disciplined throughout the process.

You are my inspiration, every day!

ACKNOWLEDGMENTS

I would like to acknowledge my family. My husband for his encouragement and unwavering support. My mother for her influence, keen perspective, guidance, and unconditional love. My siblings for keeping me well-grounded. And all other family and friends for their understanding of this time-consuming process that kept me away from many family events.

I acknowledge my advisor and graduate committee members. To my research advisor, Dr. Levon Esters, thank you for believing in my potential. I appreciate your support, guidance, and leadership. I am grateful for your invaluable insightfulness as an educator and mentor, which helped me arrive at the completed work herein. Dr. Brenda Capobianco, thank you for your support, which helped me both academically and personally. I am grateful for the opportunity to work with you, which provided focus and increased productivity. Your guidance helped me grow as a researcher and cross the finish line. Dr. Jonathan Bostic, thank you for serving as my committee member. Your support and guidance further expanded my knowledge of and interest in mathematical modeling. Dr. Pamala Morris, thank you for your mentorship and for broadening my knowledge of elementary education. I enjoyed our many interesting conversations. Dr. Mark Tucker, thank you for deepening my knowledge of research design. Your critical eye helped me fine-tune aspects of my research.

Last, I acknowledge the helpful administrators and my fellow students who provided much-appreciated support and encouragement in carrying out this research.

Other Acknowledgements:

Ideas expressed in this three-article dissertation stem from grant-funded research by the National Science Foundation Grant No. 1513256. The authors' opinions, findings, conclusions, or recommendations do not necessarily reflect the National Science Foundation's views

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Donovyn Simmons, a young scientist-in-the-making and student content reviewer of the Agricultural Sciences Model Eliciting Activities

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ABSTRACT

Contextual learning experiences using integrated STEM, agricultural sciences (AgS), and mathematical modeling (model eliciting activities [MEAs]) can be a powerful approach to engage students from urban areas in STEM literacy, career exploration, and community awareness. This three-study dissertation contributes to: (1) an innovative framework for an MEA design process and features; (2) an innovative model for MEA research and implementation; and (3) assessment data of students' interest in and motivation to learn integrated STEM and AgS, all of which culminated in the novel MEAs that facilitated contextual learning experiences that use AgS contexts. This study also provides insight into innovative teaching and learning instructional approaches aligned with Common Core State Standards (CCSS) and Next Generation Science Standards (NGSS). In particular, mathematical modeling, an emphasized topic in elementary grades' standards and curriculum, is addressed. This work draws from a larger, nationally funded project that examined integrated STEM learning experiences and teacher development. In the context of this dissertation project, I designed, developed, implemented, and assessed seven AgS MEAs. Each of the AgS MEAs addressed a local societal challenge (i.e., health and human diet, food security/insecurity, alternative energy, and green space utilization). The first study describes a process for designing and developing AgS MEAs. Data sources for this qualitative study included iterative documentation and expert evaluations. The central finding of this study was a process for designing and developing AgS MEAs. The second study describes a model for MEA research and implementation. Data sources included semi-structured teacher interviews, recorded teacher development sessions, and documented expert consultations. The central finding of this study was a model for implementing MEAs which supports contextual teaching and learning, self-regulated learning, culturally relevant pedagogy, multiple contexts, authentic assessment, and interdependence. The third study assessed students' interest in and motivation to learn STEM and AgS. Data sources included topic-related questionnaires. Findings from this study suggest that AgS MEAs may positively promote interest in and motivation to learn AgS, STEM, and STEM career exploration.

CHAPTER 1. INTRODUCTION

1.1 Overview

In this dissertation thesis, I present a series of novel mathematical modeling learning activities, agricultural sciences (AgS) focused model eliciting activities (MEAs), that were designed with the intention to improve the integration of science, technology, engineering, and mathematics (STEM) and AgS contexts into the planned sequence of K-12 curriculum. MEAs are real-world, client-driven problems that require students to develop a mathematical model of a procedure/product (Lesh & Doerr, 2003; Zawojewski et al., 2008). MEAs facilitate STEM learning by developing students' problem-solving abilities and conceptual understanding through sense-making (Hamilton et al., 2008; Lesh & Doerr, 2003).

The overarching implication of this dissertation thesis work is to increase the number of academically prepared students to fill U.S. STEM jobs. According to a U.S. Department of Education report, only 20% of high school graduates in the U.S. are academically prepared for college-level coursework in STEM majors (Herman, 2019). Mathematical modeling is an emphasized topic in elementary grades' standards and curriculum (Common Core State Standards Initiative ([CCSS], 2010). Mathematical modeling is addressed in CCSS as a viable instructional method to enhance students' skills in critical thinking, problem-solving in real-world contexts, and improved application of mathematics (Lesh & Doerr, 2003; Mousoulides & English, 2011; Stohlmann, 2013).

A model is a conceptual system(s) that explains, describes, or represents another system and has elements, operations, and relations that allow for logical relationships to emerge (Lesh & Doerr, 2003). As a representative system, models can be helpful in structuring experiences. A model is often not sufficient to completely describe the system it represents, but if it is valid, it closely approximates the system without being unnecessarily complex (Zawojewski et al., 2008).

Mathematical modeling is a type of modeling that uses mathematics to represent, mimic, or predict the behavior of real-world processes. The role of mathematization in modeling is fundamental to how students consider mathematics valuable and essential for immediate application in their everyday lives. Mathematical modeling is crucial to learning mathematics and vital in learning a wide variety of other disciplines such as science, technology, engineering, etc.

Translating a real-world problem into a predictive mathematical form is the essence of mathematical modeling. Doing so clarifies the problem by identifying the significant variables, making predictive approximations, and demonstrating a deeper understanding of the problem based on fundamental theories. The mathematician Henry Pollak (2007), a strong advocate of incorporating modeling into the mathematics curriculum at all levels of education, argued that all students must learn mathematical modeling to use mathematics in their daily lives, as citizens, and in the workforce (Cirillo et al., 2014; Pollak, 2007). Mathematical modeling can also support learning mathematics by increasing the level of motivation, comprehension, and retention.

Models and modeling perspective (MMP) (Lesh & Doerr, 2003) on teaching and learning posit that modeling is an iterative, designed based process that is essential to "future-oriented fields ranging from AgS to aeronautical engineering (Lesh & Doerr, 2003, p. 10). Well-developed modeling activities involve problematic situations that "are defined to be goal-directed activities in which adaptations of existing ways of thinking about givens, goals, and possible procedures" must be made (Lesh & Zawojewski, 2007, p. 319). The MMP suggests using MEAs as one potential research and pedagogical practice to address the critical issue of problem-solving and modeling as related to STEM disciplines.

MEA pedagogical practice grew as a means for mathematics education researchers to observe the development of student problem-solving competencies and the growth of mathematical cognition (Hamilton et al., 2008; Lesh & Doerr, 2003). Researchers have used MEAs in the classroom to investigate K-12 and first-year college students' thinking and learning (Hamilton et al., 2008; Lesh & Doerr, 2003). Researchers and educational practitioners have used MEAs in the classroom to identify highly gifted and creative students (Chamberlin & Moon, 2005; Coxbill et al., 2013; Hamilton et al., 2008). Researchers and practitioners have also used MEAs in the classroom to assess students' working conceptual knowledge and help students develop problem scoping skills to solve mathematical modeling problems (English, 2003; 2009; Glancy et al., 2018; Hamilton et al., 2008;). Researchers have used a few notable MEAs to illustrate distinguishing characteristics of MEAs (Hamilton et al., 2008), which include the *Volleyball* (Lesh & Doerr, 2003), *Summer Jobs* (Chamberlin, 2005), and the *Big Foot* problems (Lesh & Harel, 2003). The *Paper Airplane* problem (Hamilton et al., 2008) was used by middle school and freshman engineering students at Purdue University. Moore et al. (2006) used four different MEAs to assess team effectiveness during complex mathematical modeling tasks. Lastly, Bostic (2012) used MEAs to illustrate how problem-solving can be taught in three distinct ways (i.e., *teaching about*, *teaching for*, and *teaching through* problem-solving).

Six principles guide the design of MEAs (Zawojewski et al., 2008). These six design principles require that all MEAs include: a) realistic context – an authentic STEM-related problem; b) self-assessment – an opportunity for student teams to self-assess the usefulness of the model; c) an effective learning prototype – a globally generalizable or modifiable procedure/prototype; d) model construction – a math model of a procedure/product; e) model shareable and reusable – shareable and reusable for similar purposes; and f) model documentation – a procedure/product description. These principles, developed by math education researchers for elementary school classrooms (Zawojewski et al., 2008), were adapted for engineering courses and hold promise for instruction in AgS and other STEM disciplines (Lesh & Doerr, 2003). Figure 1.1 describes each of the six MEA design principles.

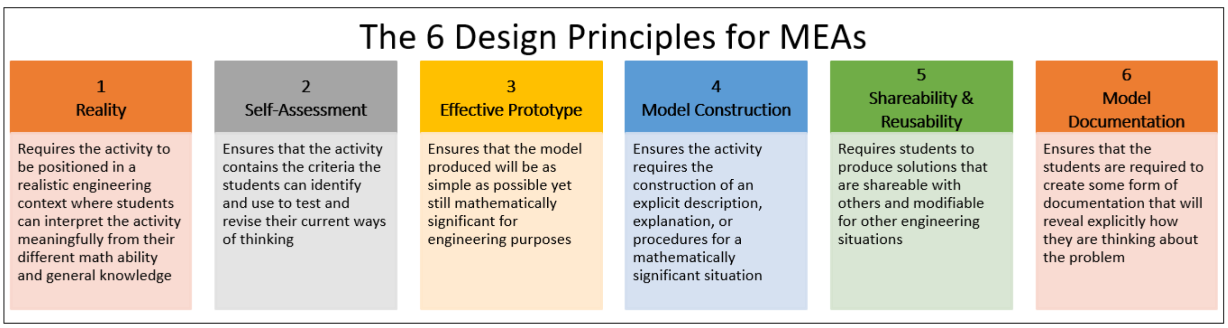
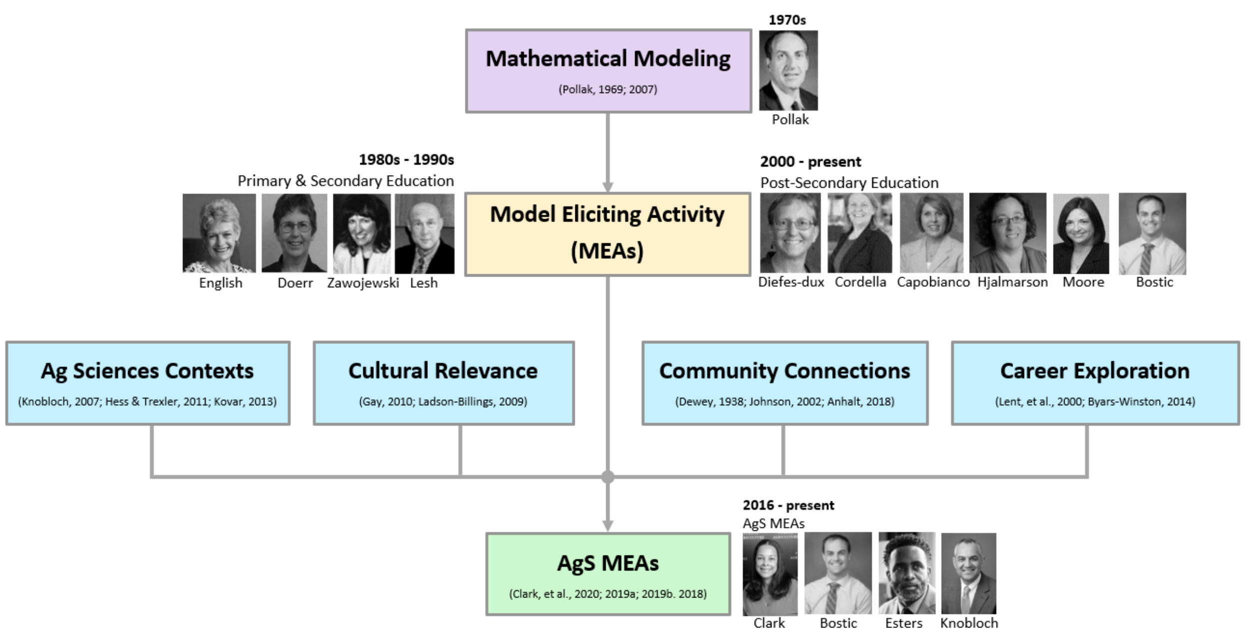


Figure 1.1. Six MEA Design Principles

AgS are logically linked to many of the 21st century's grand challenges for sustaining improved life on the planet, identified by the National Academy of Engineers ([NAE], 2009). The AgS (i.e., health, energy, environment, food) are interdisciplinary areas that have been mainly underexplored as a context for K-12 real-world engineering-based rich problem-solving tasks culturally relevant to one's environment. AgS is a dynamic approach to engage students in contextual learning because AgS consists of food, plants, and animals. Students can make real-life connections to areas relevant to their everyday lives.

Figure 1.2 illustrates the evolution of MEAs and mathematical modeling in K-16, where in the 70s, Pallak (2007) urged for modeling to be integrated into mathematics teaching and learning. Throughout the 80s and 90s, Lesh and colleagues (English 2003; 2009; Lesh & Doerr, 2003; Lesh & Zawojeski, 2007) brought math modeling activities called model eliciting activities (MEAs) into primary and secondary education through classroom research. From 2000 to the present, Diefes-Dux and colleagues (Bostic, 2012; Capobianco, 2011; Cordella, 2008; Diefes-Dux et al., 2008; Moore et al., 2006) introduced MEAs to post-secondary engineering education. Leveraging off work done over the past four decades with MEAs, this dissertation work filled the gap in MEA literature by integrating agricultural sciences contexts (Hess &Trexler, 2011; Knobloch, 2007; Kovar, 2013) and what I have termed as the three Cs (i.e., cultural relevance) (Gay, 2010; Ladson-Billings, 2009), community connections (Anhalt, 2018; Dewey, 1938; Johnson, 2002), and career exploration (Lent et al., 2000; Byers-Winston, 2014) into what is called agricultural sciences focused MEAs (Clark et al., 2020; 2019a; 2019b; 2018). Cultural relevance occurs through culturally relevant pedagogy that draws connections between students' norms and the AgS MEA topic using supplementary activities. Community connections occur through local community partners who work within the community to engage students through face-to-face or virtual classroom visits. Career exploration occurs through local STEM professions working within the community to engage students in STEM careers through face-to-face or virtual classroom visits.



Note. Ag Sciences contexts, cultural relevance, community connections, and career exploration are the novel characteristics of AgS MEAs.

Figure 1.2. Background of Scholarly Contributions of Mathematical Modeling and MEAs

Seven AgS focused MEAs were designed, developed, and implemented for this dissertation thesis. The novel characteristics of the AgS MEAs are that they: (1) aligned with both CCSS (2010) and NGSS (2013); (2) were used as a tool for researchers and educational practitioners to assess interest in and motivation to learn STEM and AgS; (3) are based on real-world societal challenges using AgS contexts (i.e., health and human diet, food security/insecurity, alternative energy, and equitable green space utilization); (4) are contextually situated in the local community and industry issues; (5) aligned with cultural referents to enhance students' sense-making of their lived experiences in STEM contexts; and (6) are useful in providing educational practitioners with knowledge resources to partner with local community organizations, local colleges, and universities and other local STEM networks to enhance students' knowledge, skills, and attitude toward STEM careers. Each of the seven AgS MEAs addresses a societal challenge (i.e., health and human diet, food security/insecurity, alternative energy, and green space utilization). Table 1.1 list all seven AgS MEAs and the key questions each AgS MEA addressed.

Table 1.1. AgS MEAs, Title, Challenge, and Key Questions Addressed

	AgS MEA Title	**Societal Challenge**	**Key Questions**
1.	Healthy Food Choices	Health & Human Diet	How do consumers use the Nutrition Facts Label information to make healthy food choices?
2.	Renewable Energy	Renewable Energy	What are ways we can harness renewable energy for use in our everyday life?
3.	Urban Green Spaces	Urban Green Space	How does access to green spaces influence the quality of life for residents in urban neighborhoods?
4.	Food Security / Insecurity	Food Security & Safety	How can a community contribute to increasing the availability of healthy food?
5.	Urban Green Spaces 2.0	Urban Green Space	How do design and access to green spaces influence the quality of life for residents in urban neighborhoods?
6.	Healthy Food Choices 2.0	Health & Human Diet	How do consumers use the Nutrition Facts Label information to make healthy food choices?
7.	Renewable Energy 2.0	Renewable Energy	What are some ways to increase access to renewable energy?

Note. 2.0 indicates a revised version of the AgS MEA.

In the following four sections of this chapter, I briefly discuss the critical problems that this body of work addresses: (1.2) and summarize the three studies (1.3).

1.2 Critical Problems

According to a report by the Education Commission of the States, STEM jobs are projected to grow 13% by 2027 as compared to 9% for non-STEM jobs (Ryan, 2021). According to a 2018 article from Pew Research Center, overall employment in STEM occupations has grown 79% since 1990, increasing from 9.7 million to 17.3 million (Graf, 2018). In an era of scientific triumph where most five-year-old children can operate technological equipment, studies show that by fourth grade, many students have settled into a career direction that becomes more difficult to change as they age (Falco, 2017; Wyss et al., 2011). Early adolescent years (ages 9-12) are when students form beliefs about their ability and confidence as learners regarding seating goals to strive for and achieve academically (Falco, 2017; Grossman & Porche, 2013; Wyss et al., 2011). For this reason, elementary grades (i.e., K-6) are an especially critical juncture in elementary grade level students' career development and decision-making process (Falco, 2017; Grossman & Porche, 2013; Wyss et al., 2011). Several studies indicate that students begin to explore and acquire career-related interests, attitudes, and self-beliefs about their ability to achieve careers in certain domains as early as fourth grade (Falco, 2017; Grossman & Porche, 2013; Wyss et al., 2011). By the time students reach the elementary school years, they have already experienced critical metacognitive awareness related to their motivation, self-concept, self-efficacy, and achievement in their career lifecycle (Grossman & Porche, 2013; Wyss et al., 2011). During this period, STEM career self-efficacy is shaped by positive reinforcement messages from family, peers, teachers, and other social contexts (Grossman & Porche, 2013; Wyss et al., 2011). However, a significant problem that contributes to the widening gap between students who pursue a career in STEM and students who do not is the lack of academic preparation in STEM subjects, specifically at the elementary school level (Herman, 2019; Mattern et al., 2015; NASEM, 2020; Stithole, 2017). The National Academies of Sciences, Engineering, and Medicine ([NASEM], 2020) confirmed this problem, which found that roughly 66% of U.S. students in urban schools are not proficient in STEM subjects such as mathematics and science at the end of eighth grade.

As of 2021, according to a U.S. Department of Education report, only 20% of U.S. high school graduates are prepared for college-level coursework in STEM majors (Herman, 2019).

Additionally, only one in five STEM college students feel that their K-12 education prepared them for STEM college-level courses (Herman, 2019). The lack of academic preparation in the elementary grades fuels the widening gap between high school students who are prepared to study STEM subject matter that prepares them to pursue a STEM degree and high school students who are simply not prepared. Lastly, more concerning is that a 2020 study projected that the potential impact of COVID-19 school closures on academic achievement would result in many students starting the 2021/2022 school year less prepared to study STEM subject matter (Kuhfeld et al., 2020).

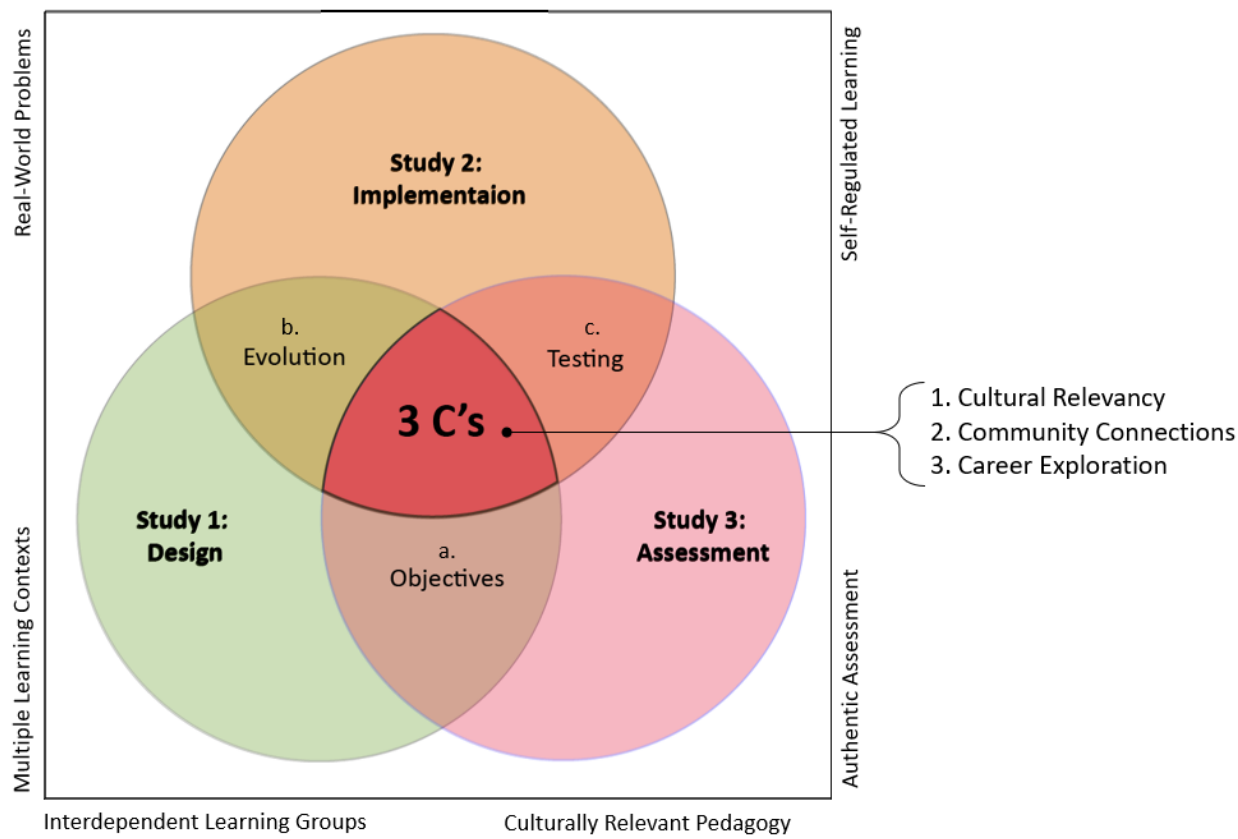
1.3 Summary of Three Studies

My research provided a vehicle to integrate STEM and AgS into the elementary curriculum easily. This work contributed to students' interest in and motivation to learn more about STEM, AgS, and STEM careers. Additionally, this work helped connect students to local community organizations, local colleges and universities, and local STEM industries. AgS MEAs require students to reflect on their lived situations and make connections between food insecurity versus food security, health, and diet in the context of childhood obesity, the affordance of renewable energy, and equitable access to green spaces.

The overarching theme of my dissertation is contextual teaching and learning. My three studies are framed by the six tents of contextual teaching and learning: (1) real-world problems – a lesson is based on a realistic situation to solved; (2) learning in multiple contexts and settings – cognitive science learning theories suggest that knowledge and learning are situated in particular physical and social contexts; (3) self-regulated learning (SRL) – SRL occurs through awareness of one's thinking, development, learning strategies, and sustained motivation; (4) cultural relevant pedagogy – teaching and learning that is anchored in culturally and environmentally relevant content; (5) authentic assessment – an assessment that challenges students to apply their academic knowledge to realistic situations; and (6) interdependent learning groups – cooperative learning (Johnson, 2002; Sears & Hersh, 1998). An emphasis is placed on what I have termed the three Cs (i.e., cultural relevancy, community connections, and career exploration). The three Cs are the connecting points for each of the three studies. I also employed design-based research protocols (Herrington et al., 2007; Reeves et al., 2005; Van den Akker et al., 2006) to guide the design and development of each study.

The main contributions from this work include a design process for developing AgS MEAs, a framework for implementing AgS MEAs into the K-12 curriculum, and an assessment of the AgS MEAs that suggests that AgS MEAs may increase students' interest and motivation in STEM learning.

Figure 1.2 illustrates a Venn diagram of the three studies where the overlapping objective for each study is identified by the letter a, the objectives for design and development of the AgS MEAs; b, the evolution of each of the AgS MEAs, and c, testing of the AgS MEAs. Figure 1.3 also illustrates how the three studies are framed by the six tents of contextual teaching and learning and how the three Cs align across each of the three studies.



Note. The intersections of each of the three studies are indicated by: a) objectives, b) evolution, and c) testing in the Venn diagram.

Figure 1.3. AgS MEAs Ven Diagram

The purpose of the first study, a qualitative, exploratory multiple case study, was to describe a process for designing and developing AgS MEAs. The research question that guided this study was: "What are important design features when developing AgS MEAs?" The guiding frameworks were models and modeling perspective, and design science. The two key data sources that informed this study were an iterative cycle of evaluations from content specialists – data related to developing the AgS MEAs and expert evaluations – formal evaluations by expert panel members. A signature finding from this study was a process for designing AgS focused MEAs that addresses elementary content standards. This study was published in the *Journal of School Science and Mathematics Journal*.

The second study, a qualitative case study, identified and characterized essential structural and interactional implementation components of an integrated STEM curriculum innovation (i.e., AgS MEAs). Structural components support procedural elements and communicate what learners need to know. Structural components inform the ways that teachers implement the AgS MEAs. Interactional components support teachers' and students' behaviors, interactions, and practices during implementation. The data sources that informed this study included semi-structured teacher interviews (individual and focus group), recorded teacher development sessions, and documented expert consultations. The questions that guided this study were: (1) "What are the structural and interactional components of an integrated STEM curriculum (i.e., AgS MEAs)?" (2) "How was the engineering design process utilized to identify revisions and modifications to an integrated STEM curriculum (i.e., AgS MEAs)?" Findings of this study indicated six recurring structural components (i.e., cover page, advanced organizer, discussion topics, problem-solving strategies, and MEA assessment rubric) and six recurring interactional components (i.e., student mentorship, problem identification, culturally relevant pedagogy, team roles & responsibilities, reflection, and supportive technology). This study provided educators with a means to introduce contextual teaching and learning (i.e., self-regulated learning, culturally relevant pedagogy, multiple contexts, authentic assessment, and interdependence into the classrooms). This study was submitted to the *Journal of Agricultural Education*.

The third study, a quantitative study, examined urban elementary student's interest and motivation in agriculture, food, natural resources (AFNR), STEM career choices, and STEM learning activities after participating in AgS MEAs. The two research questions guiding the study were: (1) "How does interest and motivation in AgS MEAs compare between students who engaged in two versus four MEAs?” (2) “How does interest and motivation in AgS contexts compare between students who engaged in two versus four MEAs?” This study's findings suggest that AgS MEAs may positively promote interest in and motivation to learn AgS and STEM while participating in integrated STEM learning activities. This study indicated no difference in interest and motivation between fifth- and sixth-graders after participating in the AgS MEAs. This study examined differences in urban elementary students’ interest and motivation to learn AgS and participate in integrated STEM learning activities. This study was submitted to the *Journal of Agricultural Education*. Figure 1.4 lists essential components for each of the three studies.

Study 1	Study 2	Study 3
Title: *A Design Process for Developing Agricultural Sciences Focused Model Eliciting Activities*	**Title:** *Identification of Essential Implementation Components of Integrated STEM Curriculum*	**Title:** *Assessing Students' Interest and Motivation in STEM through Agricultural Sciences Focused MEAs*
Problem: There was no roadmap on authoring AgS MEAs that include the three Cs, i.e., culture, career, and community.	**Problem:** There was no process for identifying essential implementation components of AgS MEAs.	**Problem:** Prior MEA research efforts focused on how students think and learn.
Purpose: This exploratory study describes a process for designing and developing AgS MEAs.	**Purpose:** This exploratory study characterized essential structural an interactional implementation components of AgS MEAs.	**Purpose:** This quantitative study examined student’s interest in and motivation to learn STEM.
Research Question: What are important design features when developing AgS MEAs?	**Research Questions:** What are the structural and interactional components of AgS MEAs? How was the engineering design process utilized to identify revisions and modifications to the AgS MEAs?	**Research Question:** How does interest and motivation in AgS MEAs compare between students who engaged in two versus four MEAs? How does interest and motivation in AgS contexts compare between students who engaged in two versus four MEAs?
Frameworks included models and modeling perspective (Lesh & Doerr, 2003) and design science (Middleton, et al., 2008).	**Frameworks** included innovation implementation (Century & Cassata, 2014) and engineering design process (Moore et al., 2013).	**Framework** guiding the study was self-determination theory (Deci & Ryan, 2012).
Participants: Two expert panels included content specialists and elementary school teachers, acted in concert to develop and refine the AgS MEAs.	**Setting and Participants:** A 39-acre urban Midwestern magnet school. Seven elementary school teachers.	**Setting and Participants:** A 39-acre urban Midwestern magnet school. Two 5th and 6th grade classrooms (*N*=67) and 4 teachers.
Methods included a qualitative multi-case study (Yin, 2006).	**Methods** included a qualitative case study (Yin, 2017).	**Methods** included a quantitative questionnaires (Creswell, 2003).
Data sources included an iterative cycle of evaluations from content specialists and a panel of elementary school teachers. **Data analysis** involved an inductive analysis approach (Creswell, 2012) to identify emerging themes across cases.	**Data sources** include semi-structured interviews and focus groups. **Data analysis** involved a four-step constant comparative analysis (Creswell, 2012) to identify emerging themes.	**Data sources** included an intrinsic motivation inventory and an agricultural sciences interest inventory. **Data analysis** involved statistical analysis to include reliability scores, frequencies, and t-test scores.
Findings provide a signature finding is a six-step process for designing AgS MEAs that address elementary content standards.	**Findings** provide researchers and educators with a process for identifying implementation components.	**Results** indicated a positive difference between engagement in four versus two MEAs.

Note. The three studies are presented in chapter 2 (study 1), chapter 3 (study 2), and chapter 4 (study 3).

Figure 1.4. Essential Components of the Three Studies

The remaining chapters of this dissertation are organized as such. Chapter two, a version of study one, was published in the *Journal of School Science and Mathematics*. Chapter three covers study two and in review for publication in the *Journal of Agricultural Education*. Chapter four covers study three, also in consideration for publication in the *Journal of Agricultural Education*. Chapter 5 concludes this dissertation.

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CHAPTER 2. A DESIGN PROCESS FOR DEVELOPING AGRICULTURAL SCIENCES FOCUSED MODEL ELICITING ACTIVITIES

A version of this chapter has been previously published in School Science and Mathematics.

Bostic, J. D., Clark, Q. M., Vo, T., Esters, L. T., & Knobloch, N. A. (2021). A design process for developing agricultural life science-focused model eliciting activities. *School Science and Mathematics*, *121*(1), 13-24.

2.1 Abstract

Agricultural sciences (AgS) topics include but are not limited to: (a) agriculture and the environment, (b) culture, society, and economy, and (c) energy. These topics can come up during mathematics and science instruction in the elementary grades (i.e., K-6) and offer learning opportunities. One way for agricultural life science topics to be part of such instruction is through tasks that encourage problem-solving. Model eliciting activities (MEAs) are tasks that promote problem-solving, draw upon real-life experiences, and have the potential to engage in learning across multiple disciplines. The purpose of this manuscript is to describe a qualitative, exploratory multiple case study. This study answers the research question: What are important design features when developing AgS MEAs? Results from this study provide a viable roadmap as an approach to develop MEAs that address AgS issues. This roadmap includes six stages: problem identification, assessing developmental readiness, identifying potential engagement in the MEA, considering pedagogical sup- ports, practitioner reviews, and finally, field testing.

Keywords: agriculture, case study, design, elementary, life science, model eliciting activity, STEM

2.2 Introduction

Agricultural literacy, inclusive of technology, science, and human dimensions, involves civic, cultural, and economic understandings (Knobloch et al., 2007; Meischen & Trexler, 2003). Organizations such as the National Center for Agricultural Literacy (NCAL, 2013) have emphasized the importance of agricultural literacy in the K-12 classrooms, moving past narratives of farming to a more national global perspective of conservation and humanitarian issues (Hess & Trexler, 2011; Trexler et al., 2013). The NCAL defines meaningful agricultural sciences (AgS) topics through five key topics: (1) agriculture and the environment, (2) culture, society, economy, and geography, (3) food, health, and life- style, (4) plants and animals for food, fiber, and energy, and (5) science, technology, engineering, and math. However, classroom implementation of complex socio-scientific issues is challenging, particularly at the elementary level (Sadler & Zeidler, 2005), where teachers might struggle to glean what foundational knowledge young students have.

One potential avenue for growing student resources and understanding complex AgS topics is using model eliciting activities (MEAs; Lesh et al., 2000). Aligned with both Common Core State Standards Initiative ([CCSSI]; 2010) and Next Generation Science Standards ([NGSS]; 2013), MEAs are important mathematical tasks that promote reasoning, sensemaking, problem-solving, and content learning (Consortium for Mathematics and its Applications [COMAP], 2019; English, 2009; Lesh & Harel, 2003). Modeling, which has been explored since 1969 when Pollak urged for modeling to be integrated into mathematics teaching (Pollak, 2007), is recognized in the CCSSI (2010) as a mathematical practice. Advocacy continues for its inclusion at all grade levels (COMAP, 2019), especially at the elementary grade levels (Felton et al., 2015). This research study provides a means for future research on MEAs. This study also offers a vehicle through MEAs to introduce cross-curricular topics, such as agricultural sciences (AgS), as part of classroom learning in the elementary grades. Given the potentially productive synergy of leveraging MEAs to learn about AgS phenomena, we asked: What are some important design features when developing AgS MEAs? What would a process model of an AgS MEA development entail?

2.3 Background

2.3.1 Agricultural Sciences and Education

Three AgS factors show potential to enhance students' STEM literacy and STEM career exploration: the interdisciplinary nature of AgS, the familiarity of AgS topics with most students, and connections to STEM (Ryu et al., 2018; Powell & Agnew, 2011). AgS contexts can facilitate the creation of MEAs that are culturally relevant to students' environment, societal challenges (e.g., food, environment, energy, and health), and local urban community issues, which are relevant across varying cultures and environments (Agriculture in the Classroom [AITC], 2014; Knobloch et al., 2007; Meischen & Trexler, 2003). Literature supports elementary school level students' ability to engage with complex natural and human needs (Knobloch, 2008; Frick, 1993; Gibbs, 2005). The challenges of meeting sustainable clean water, food, medicine, urban infrastructure, and clean energy needs situate AgS as an ideal context for young students to explore rich, culturally relevant real-world problem-solving tasks (Mabie & Baker, 1996).

2.3.2 Modeling Eliciting Activities (MEAs)

MEAs are rich tasks that support students in considering and reflecting upon real-world problems or issues and making connections between topics within and across content areas (Abassian et al., 2020; COMAP, 2019; Lesh & Zawojewski, 2007). MEAs are problems, not exercises, which make them differ from many of the tasks students experience in classrooms every day (Abassian) et al., 2020; COMAP, 2019; English, 2009). A *problem* is a task that requires critical thinking because: (a) the solution strategy is unclear to the individual, (b) the solution and number of solutions is uncertain, and (c) may be solved in more than one way (Schoenfeld, 2011). *Exercises* are tasks meant to foster students' facility and speed with a known procedure (Kilpatrick et al., 2001).

MEAs draw upon a problem-solving cycle that encourages individuals to: (1) read the problem; (2) construct a means to solve the problem; (3) execute a strategy and reflect upon its result; and (4) consider alternative ways to solve the problem (COMAP, 2019; Crismond & Adams, 2012; Cunningham & Kelly, 2017; Lesh & Harel, 2003). This modeling cycle is unique from other thinking that students might use with other mathematical tasks (Abassian et al., 2020; COMAP, 2019). MEAs and modeling-focused tasks do not necessarily have one or more correct answers. However, answers can be better or worse than others for reasons such as the solution is more or less effectively grounded in the real-world context, limitations, and assumptions used while problem-solving may or may not have been fully realized (Clement, 2000; COMAP, 2019). MEAs are ideal tools for connecting content across curricula and engaging students in mathematizing the real world (English, 2009).

2.3.3 Example of MEAs

There are several MEAs discussed in the literature. We purposefully highlight two examples, a historical and contemporary MEA, to provide context for their uses. The historical MEA is referenced frequently in the literature. Another purpose for describing these MEAs is to provide the reader with a sense of these unique tasks. A third purpose is to share how MEAs might be used across elementary contexts as tools for promoting cross-curricular learning. The first MEA involves upper elementary students (ages 10-13) and is an example of MEAs outside the USA. The second example is intended for upper elementary students and aligns with the CCSSI (2010).

2.3.4 Example 1: Chip Choice MEA

English (2003) enacted a multiyear MEA with students in grades 5–7 to help consumers decide "what is your favorite snack chip?" While there is no single best or favorite snack chip shared by all consumers, there are ways to help consumers consider all the possible snack chips and what features of chips they do and do not prefer. English (2003) conjectured that such a model could be replicated and modified for other food such as drinks and candy. Elementary-aged students are capable of doing MEAs, and early engagement with them connects real-world problems with in-class learning and supports students' problem-solving (English, 2003; Stohlmann, 2013). "It is important to begin mathematical modeling in the elementary grades…" (Stohlmann, 2013, p. 60) because it can promote problem-solving skills (English, 2009).

2.3.5 Example 2: Amusement Park MEA

Bleiler-Baxter and colleagues (2017) developed a task to promote modeling with mathematics to experience modeling as a decision-making process. Students were provided with wait times for amusement park rides during various moments in a day; albeit, the table with the wait times is incomplete. The task requires students to complete the rest of the table and justify their decisions based on the table's data. There is no single correct solution set for the table. The expectation is that problem solvers iteratively work through a three-part cycle while modeling: (a) simplify the problem where appropriate, (b) engage in relationship mapping, and (c) analyze the situation appropriately to determine if the conclusion models the situation. Students arrived at a reasonable solution through this cycle that acknowledges the problem's assumptions and limitations and accurately reflects the problem's situation.

Taken collectively, modeling with mathematics and MEAs have a rich history over the last 20 years. However, the two examples presented provide no details about how to author MEAs. Their focus is squarely on research questions related to the use, not the development of MEAs. Although design principles for MEA development (described later in this article) might be evident in a final product, a straightforward process to guide potential MEA developers, especially those new to MEA development, lacks. The final product is often presented alone, and the process is left undefined, which is problematic for those who want to design MEAs. The six principles of MEAs provide a framework for learners' experiences, yet the principles do not communicate a process for developing MEAs. Discussion of the MEA development process is warranted if research with MEAs aims to impact other scholars broadly. This research study aims to fill this literature gap by providing readers with a design process for MEA development, which successfully developed MEAs linked with AgS contexts. This design process resulted from three iterations of MEA development, empirically testing it on a fourth MEA. The other design processes, their strengths and limitations for those processes, and reasons were less effective than those presented in the findings. This study has the potential to inform scholars seeking to author MEAs for their research and teacher educators who may want to foster MEA development in their coursework or professional development.

There are numerous instances of MEAs being developed and shared in the scholarly and practitioner literature, yet few connect with AgS issues and the CCSSI. The authors conducted a literature search and did not locate MEAs designed for elementary students related to AgS content. Because of this gap and the potential for using MEAs to engage students in AgS contexts, this manuscript aims to describe a design process that might guide others in developing MEAs for elementary-aged students, specifically MEAs that have an AgS perspective and address grade-level mathematics and literacy standards. Like those shared earlier, examples do not present an explicit design process for others to follow or adapt; hence, the authors share a design process that stems from engaging in MEA development three times over a 1-year period and empirically testing the process during a fourth MEA. There were revisions to the design process each time, which ultimately led to improvements while developing the design process that is shared in this manuscript.

2.4 Conceptual Frameworks

This study is guided by two distinct perspectives: (a) the models and modeling perspective, which links the MEAs conducted in this research study to the models and modeling perspective, and (b) the design-based research perspective that guided MEA development.

2.4.1 Models and Modeling Perspective: Process and Principles

The models and modeling perspective is grounded mainly in work by Lesh and several colleagues (e.g., Lesh & Doerr, 2003; Lesh & Zawojewski, 2007) and has also been termed the contextual perspective (Abassian et al., 2020; Kaiser & Sriraman, 2006). Figure 2.1 provides an overview of the modeling process. Bidirectional arrows are used throughout the figure to represent the continuous self-assessment and reflection throughout the modeling process.

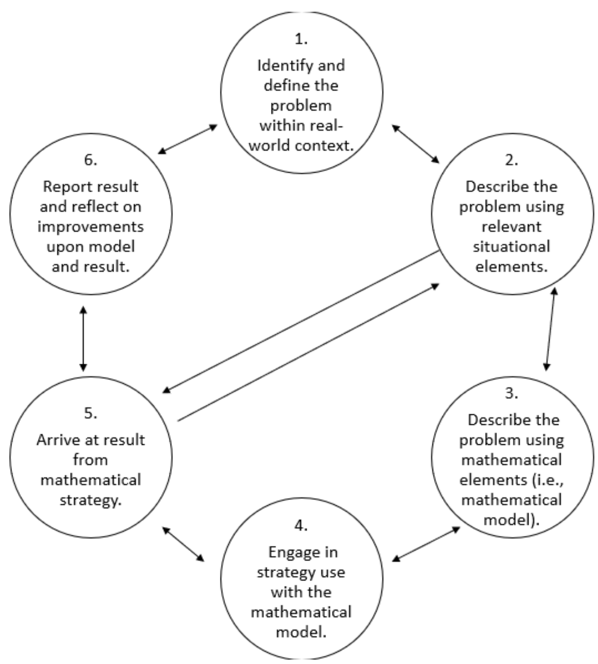

Figure 2.1. Overview of Modeling Process from the Models and Modeling Perspectives.

This models and modeling perspective begins with a problem or issue found in the real-world (Abassian et al., 2020). Then, a problem is described by the problem solver in such a way that it allows an individual to work with a simulated or modeled world. In this modeled world, an individual engages with data and information in mathematical ways to arrive at a result. This result is then verified with the modeled world. If it is not acceptable or could be better refined, then the problem solver continues to engage in mathematical problem-solving until the individual feels the mathematical result appropriately represents a solution to the problem. A final result is evaluated within the real-world context and communicated to others. It is typical for students to communicate the result in writing and to acknowledge assumptions and limitations (COMAP, 2019; Lesh et al., 2000) in the form of a memo, letter, or poster.

This modeling process has six embedded principles that guide MEA development using the models and modeling perspective (Lesh et al., 2000; Lesh & Doerr, 2003). There are six principles: (1) model construction, (2) reality, (3) self-assessment, (4) model documentation, (5) generalizability, and (6) effective prototype. *Model construction* indicates that problem solvers engaged in MEAs must document their work clearly and effectively. Thus, others might better understand their thinking, including solution paths that were not chosen. *Reality* suggests that MEA tasks must be believable. That is, a problem solver must believe that the problem could exist in the real world (Lesh et al., 2000). The problem does not necessarily exist in the problem solver's daily life and might be a societal or community-based problem. *Self-assessment* anticipates problem solver's abilities to be critical of their work and seek to improve their solution and/or solution pathway where possible. A result of self-assessment is to revise and refine the model in ways that manage assumptions and limitations associated with the model and the problem situation. *Model documentation* ensures that students document their thinking in ways that are explicit to others. This is an important principle because externalized ideas can be acted upon and explored by others during group work on the MEA. Model documentation can also promote equity during MEA work because it gives everyone a voice and power in the MEA working group. *Generalizability* implies that the solution and solution pathway can generalize to multiple contexts related to the problem described in the MEA (Lesh et al., 2000). Put another way, the solution must go beyond working for one possible context within the problem situation. Finally, *effective prototype* describes an idea that the solution (aka, model) for the MEA must be as simple and effective as possible. More complex models may be less usable by a broad audience, especially younger students (Lesh & Doerr, 2003). These six principles and the modeling process dovetail with the design-based research approach applied to this project.

2.4.2 Design Science

Design science aims to generate ideas that can respond to real problems (Middleton et al., 2008); hence, design science is ideal for MEA design research. A four-phase design approach (see Figure 2.2) was applied for this study, drawn from Middleton and colleagues' work (2008). This approach is broadly applicable because it supports developing tools, encompassing tasks, assessments, and other materials that others can revise and reuse (Anderson & Shattuck, 2012).

Figure 2.2. Four-Phase Design-Science-Based Approach to Tool Development.

Step one of the design approach is to identify and state the problem to explore. Because problems are embedded in real-life situations, it is important to identify which problem will be solved and what assumptions or limitations might be considered. This phase connects with the models and modeling principles of reality and model construction. Step two of the design process is to construct a testable model. This step connects with two models and modeling principles: model construction and generalizability. Step three of the design process is to test the model within real-world contexts. This step connects to three principles: reality, self-assessment, and effective prototype. Step four is implementing the solution. This step shares similarities with the generalizability and effective prototype principles from the models and modeling perspective. Taking a holistic view of the design-based process, it is clear that there are many shared similarities with the models and modeling perspective. These shared similarities grant MEA designer's opportunities to groundwork in both a sound methodological approach (i.e., design science research) and a robust literature base (i.e., models and modeling perspective).

2.5 Methods

2.5.1 Context and Research Design

This exploratory research is part of a multiyear National Science Foundation (NSF) funded project (#1513256) to develop, implement, and evaluate integrated culturally relevant MEAs to foster STEM learning experiences that use AgS as a context. The current research study emphasizes how AgS MEAs are developed, emphasizing the transition of theory to practice. A multiple case study (Yin, 2017) was employed to answer the research question, wherein each MEA represented a separate case. A cross-case analysis was performed to investigate themes across cases. This type of analysis has a long history of understanding how a fluid process, like curriculum development, can be parsed by providing structure in identifying patterns. For example, Venville et al. (1998) used a multiple case study to identify multiple vital integration segments between science, math, and technology within a secondary education context (e.g., competitions, school specialists, and thematic projects). Another example of cross-case analysis was able to identify connections between teacher effectiveness and student achievement (Stronge et al., 2011). A cross-case analysis was used in the present study to investigate meaningful segments of the AgS process and the considerations that went into each segment. This method is appropriate, as this project seeks to provide examples of relevant AgS MEAs which are based on research while moving MEA literature forward by identifying characteristics across multiple MEAs that would support student learning within agricultural contexts.

Agricultural Sciences MEAs. Three AgS MEAs were developed during one calendar year. Each of the three AgS MEAs focused on a major societal challenge: (1) health, (2) alternative energy, and (3) environment. To ensure cultural, career, and community connections to students' real-life experiences, each AgS MEA was connected to a relatable topic—a societal challenge connected to local community issues, a STEM career, and cultural relevance (Knobloch et al., 2007). All three MEAs were meant to attend to the models and modeling perspective and associate principles (Lesh & Doerr, 2003) and were aligned with national standards (CCSSI, 2010; NGSS, 2013). These topics were chosen due to their relevance to urban students who deal with food deserts, childhood obesity, air quality warnings, and lack of access to green spaces. These issues, which have various solutions across varying scales, require students to reflect on their personal situations and connect challenges and resources in students' local communities.

2.5.2 Design Process

The iterative nature of the design processes required the expertise of many individuals. Two expert panels acted in concert to develop and refine the AgS MEAs.

Content specialist panel. The academic panel consisted of individuals with expertise in agricultural sciences, science content, mathematics education, and culturally relevant pedagogy. This panel was responsible for the initial design and development of AgS MEAs using a culturally relevant context. They managed the iterative design process, providing design iterations and feedback on the accuracy of the AgS MEAs as recommended by the expert panel. The science, inclusive of AgS, context expert panel reviewed scientific accuracy and linked science content found within the MEA to provide consistency. A mathematics educator who had previously developed and published MEAs reviewed the fidelity of the MEAs for an upper elementary classroom, with additional attention given to addressing the six principles from the models and modeling perspective and the Universal Design for Learning (CAST, 2019) perspective. Finally, a terminally degreed education scholar with expertise in culturally relevant pedagogy served on the panel.

Elementary teacher panel. Three classroom teachers, identified with pseudonyms, were purposefully selected for the practitioner expert panel given their robust teaching credentials, experience with MEAs, and commitment to research, all while actively teaching. Each holds a license to teach grades 4–9 mathematics, reading, and at least one additional content area (e.g., Science, Social Studies, or English Language Arts). These classroom teachers have received at least 80 hours of professional development on modeling with mathematics and MEAs. They have developed and implemented MEAs regularly (at least two times per academic year) as part of their everyday instruction. Mr. Tim, Ms. Laura, and Mr. Brandon were all licensed mathematics teachers with additional credentials (i.e., Science, Social Studies, or English Language Arts). It was beneficial to have classroom teachers familiar with students' developmental readiness and content standards because the MEAs address content standards from multiple content areas.

2.5.3 Data Sources

The two key data sources that informed the design process of the AgS MEAs were iteration documentation and expert evaluations.

Iteration documentation. Data related to developing the MEAs functioned as data sources for creating a design process reported in the results. The authors of this study made individual notes during the development of MEAs about the process, created memos about team phone conversations, and drew upon email exchanges between team members. These email exchanges included rough draft versions of each MEA and reviews by team members.

Expert evaluations. Formal evaluations by members of the expert panel were conducted on each MEA. The evaluations assessed each AgS MEA by using the guiding question: To what degree does evidence within the proposed MEA address the six design principles? A rubric was developed to identify evidence or lack thereof for each design principle. Furthermore, the rubric addressed evidence of other items that were likely to communicate greater coherence within the AgS MEA and the task (e.g., connected to standards, opportunities to promote access and equity, and to what degree the outcome is a model).

Two constructed response protocols were created for specific members of the expert panel. One protocol was used solely by the mathematics educator, which addressed the six principles of the models and modeling perspective, alignment with mathematics standards, and pedagogical components (e.g., instructional aspects that supported implementing MEAs). Two sample questions from the protocol were, "In what ways does this MEA address the self-assessment principles? To what degree does this MEA support all learners' engagement in the MEA through Universal Design for Learning principles?" The other protocol was created for classroom teachers serving on the expert panel to focus on the degree to which the MEAs were ready for implementation. Two sample questions from the protocol were "How effectively does the MEA address the indicated grade-level content standards? What challenges do you perceive with implementing this MEA as part of your classroom instruction?" Other team members conducted a holistic review using their expertise as a frame.

2.5.4 Data Analysis

Data were analyzed qualitatively using an inductive analysis approach, which resulted in a theme that may be communicated as a process and or figure (Yin, 2017). First, data were read in their entirety to become familiar with all available data. Second, memos were made about the data, noting areas to examine further. Third, notes were made of specific data that seemed to highlight important moments in the MEA development process. Fourth, general impressions that were common during the MEA development process across the MEAs were underscored as possible key design features of the MEA development process. Fifth, evidence supporting (or not supporting) the framework was gathered, which came from all data sources. Sixth, the initial framework was reviewed within the context of the three MEAs and reviewed to confirm that the framework accurately reflected the ideal process. The final step was generating a figure depicting a process for constructing AgS MEAs. After refining this design process, it was empirically tested with a fourth MEA for the project.

2.6 Findings

This study's central finding is a process for designing AgS focused MEAs that address upper elementary content standards. The team tried more than one process during development—results led to a design process that best supported MEA development. Prior iterations in the design process were not as successful as the final design process (see Figure 2.3).

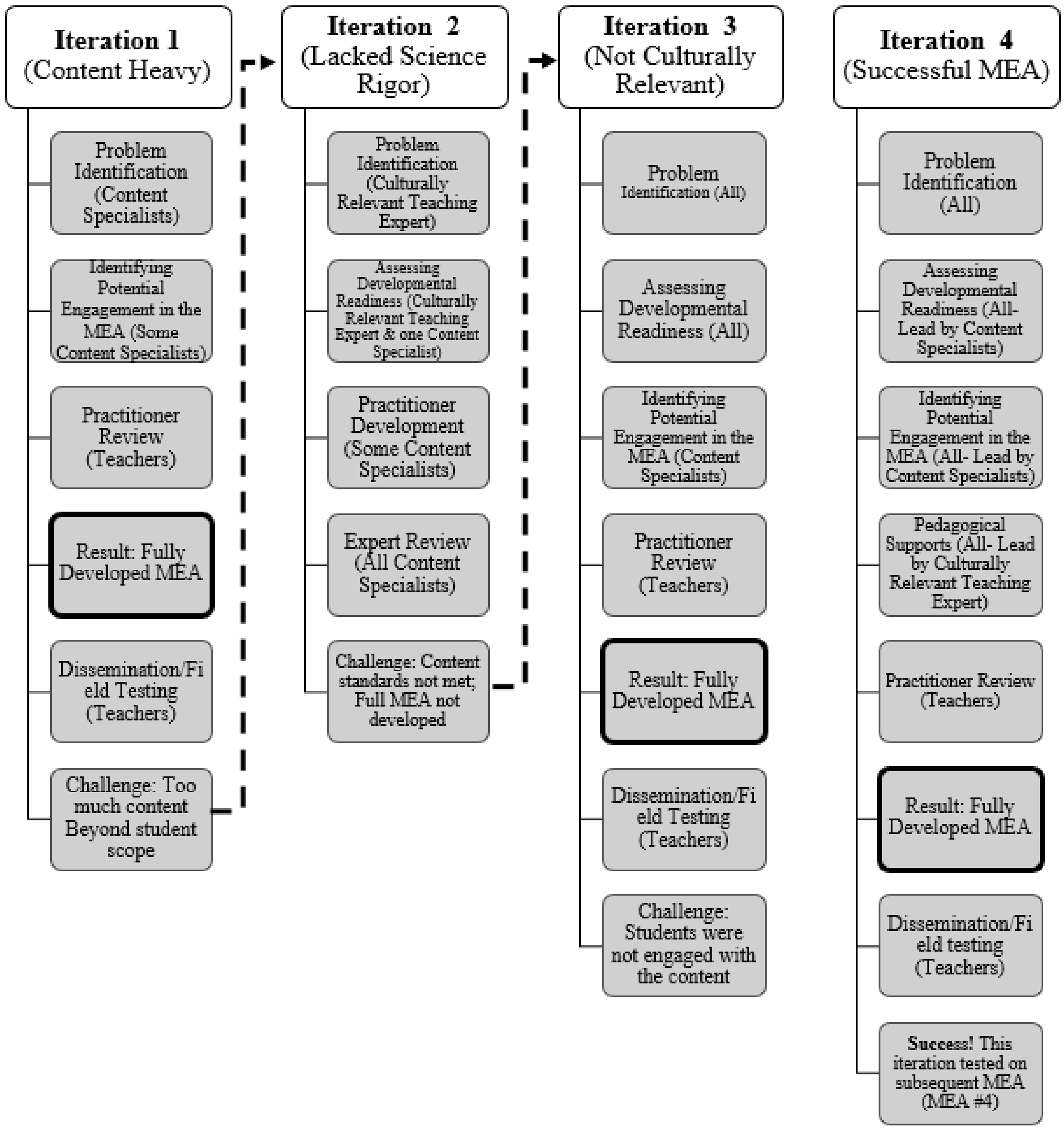

Figure 2.3. Example of Failed Iterations Leading to Idea Process

Table 2.1 indicates issues in earlier design processes. For instance, one process required a complete overhaul because the content provided a good context for an MEA but was not relevant to students' experiences. The science content did not easily lend itself to grade-level mathematics content found in the standards.

Table 2.1. Design Process Issues and Challenges.

Issue	Challenge
Too Content Heavy: Initial focus on content, ignoring developmental readiness or cultural relevance	Some problems are critically important to content and need a resolution for society (e.g., renewable energy). In an early MEA focused on renewable energy, students worked with dollar values that were not easy to contextualize. Secondarily, the MEA used settings that were difficult to understand. As a result, the MEA passed all checks, but it did not resonate well with teachers or students
Lacked Science Rigor: Starting with a non-STEM educator and all focus on pedagogical supports	Beginning with a focus on language and discussions outside of the STEM content required more energy to connect to content standards. In one iteration of the design process, the MEA design had to restart because there was no content connection to grade-level standards. Additionally, STEM content experts indicated that a particular MEA had inaccuracies, which entirely changed the math content. Thus, the MEA had to be revised.
Not Culturally Relevant: Drawing from general problems in society	While the problems chosen were significant, they were irrelevant to students or beyond developmental readiness (e.g., too abstract). For example, bringing clean water to all children worldwide is important but was not as relatable as a problem springing from students' communities.

We describe the process for developing these MEAs as iterative, much in the same way as design science allows individuals to engage in product development, self-assessment, and refinement at many stages. We argue that while internally, each iteration addressed the six design principles of MEA development, there were additional considerations when dealing with AgS MEAs. Figure 2.4 provides the most effective process in meeting our aim of developing AgS MEAs for elementary students.

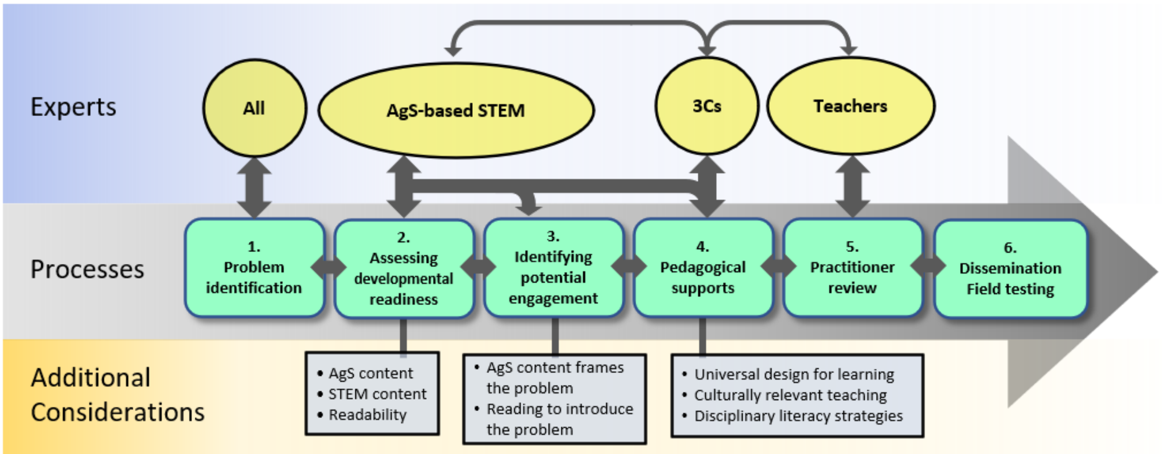

Figure 2.4. Ideal Agricultural Sciences Focused MEA Development Process.

The process (Figure 2.4) addressed essential parts of MEAs, such as the six principles of MEAs. This ideal process was created through each MEA design sequence, then empirically tested with a fourth MEA. The term ideal process is used because the final process resulting from refinement led to a more effective and more efficient method than the design process used in each prior MEA.

The first step in the process was determining the model that problem solvers might construct. At this step, the research team aimed to answer questions such as: (1) What will the model for the MEA look like? (2) What is the central question that is driving the MEA? (3) How does the model for the MEA respond to a present need that would generate buy-in from problem solvers? (4) How might students be engaged in making relevant connections to solving the problem and developing models?

The second step in this ideal process required content discussions: specifically exploring problem solvers' developmental readiness to examine content needed to understand the problem situation. MEAs naturally involve mathematics content, which was informed by grade-level standards. Grade level standards for these MEAs drew from the content standards (CCSSI, 2010; NGSS, 2013). The MEAs also drew upon key principles from AgS using NCAL standards (2013). Contextualizing AgS in an urban context was important to help teachers and students see the connections, relevance, and importance in their communities (Knobloch et al., 2007). Another concern was problem solvers' readiness to engage in reading and English Language Arts standards relevant to the content that may arise and the writing in the content standards (CCSSI, 2010).

MEAs often end with the problem solver communicating results to a broad audience through an oral and written presentation. Thus, the team considered English Language Arts standards and content areas standards (CCSSI, 2010).

The third step in constructing these MEAs was reflecting on the question: How will problem solvers engage in the MEA? The team drew upon MEAs developed by the mathematics educator involved in the project and those found on the Case Studies for Kids website (2013). These example MEAs included a motivational reading that was meant to kickstart students' engagement in the MEA. Thus, this decision to include a motivational reading remained present in the three MEAs. Finally, what content and other resources are needed for problem solvers to engage in the MEA? This led to thinking about the degree to which problem solvers might require technology to access websites, ancillary information, or further readings about AgS or other forms of science content. Decisions at this step informed the pedagogical aspects in step four.

During the fourth step, the team considered pedagogical elements that might enhance the MEA. Pedagogical elements were defined as aspects that informed the MEA task and how teachers and students might engage with the tasks. These elements were not placed above one another, and it was typical for designers to float between two or more of these aspects during a planning meeting. Considerations were taken to reflect both the mathematics and science process standards (CCSSI, 2010; NGSS, 2013). Elements of Universal Design for Learning (CAST, 2019) and culturally relevant teaching (Gay, 2010; Gutierrez, 2009) were frequent conversation topics during this phase. Finally, expectations for engaging learners in disciplinary literacy through oral and written expression and information gathering were drawn from appropriate standards (CCSSI, 2010). Results from development discussions across team members aimed to promote ideal expectations for mathematics tasks (see National Council of Teachers of Mathematics, 2014). Ideas from mathematics education literature were used to build connections to math and real-world problems. Several rounds of revisions using these topics happened as part of the process, which included all members of the content expert team.

The fifth step in the design process was delivering a preliminary MEA review by the three classroom teachers. Their summative evaluation of the entire MEA confirmed that the MEA had potential, pending their revisions, for use with students. Their feedback indicated ways to refine and revise it for use by a broad audience. One challenge and benefit of the classroom teachers who participated in this project was their modeling expertise. They acknowledged several areas where the task was likely to promote its objectives. Still, they mentioned how the success of the MEA might be hindered if classroom teachers using it did not structure the learning environment in ways that: (a) promote discussions, (b) encourage critical thinking and reflection, and (c) foster norms supportive of mathematical thinking and learning. As one example, Mr. Tim and Ms. Laura expressed in their report that “If a teacher using this MEA (#3) and doesn't have appropriate social, socio-mathematical, or mathematical norms, then this task won't be nearly as good as it is. We can tell others how good the task is, but without setting up the learning environment, there is no telling whether it will live up to that expectation.” Mr. Brandon added that “Are students prepared to talk and actively listen to each other? Is the teacher ready to encourage students to *talk about math* [emphasis added] rather than have them sit and listen to a lecture?” The design team considered all feedback to design a solid MEA, considering that implementing MEAs requires important instructional environment considerations.

The sixth and final step was dissemination for potential classroom use within the project's scope. Feedback from the classroom teachers was used to revise the MEAs and pilot them. For example, Mr. Brandon highlighted a mismatch between the intended and actual English Language Arts standards associated with one MEA. This feedback resulted in a reconnecting with the culturally relevant teaching expert because of her expertise in reading. Similar revisions happened with all MEAs, and ultimately, a final product ready for dissemination was produced.

2.7 Discussion and Implications

This study's central finding is a process for developing AgS focused MEAs that address content standards found in elementary grade levels. While the six principles for MEAs serve as a framework, they do not provide a roadmap for developing MEAs. Additionally, this process offers a way to integrate AgS into mathematics instruction. AgS topics are important and connect students with real-world situations that impact them (Knobloch, 2008; Trexler et al., 2013). MEAs foster students' connections between mathematics learned in the classroom and real-life situations (Lesh & Doerr, 2003). This research study builds upon prior research on MEAs and offers a specific design process for developing MEAs. We situate this study's results to developing AgS MEAs; however, we conjecture that this study's design process may be valuable for constructing MEAs associated with other content.

A key implication of developing this framework is to provide scholars with a viable process for creating MEAs. COMAP (2019) and other published materials offer several examples of MEAs and or information about their implementation yet, stop short of providing a roadmap, process, or framework for others interested in developing MEAs. Thus, this manuscript fills a necessary gap in the MEA literature by providing a design process and design features during the MEA process to guide future MEA development. This is particularly important due to the need for supporting cross-curricular work that fosters connections and authenticity (Knobloch et al., 2007), including AgS issues for K-12 students, where the relevance factors are not always made explicit (Martin & Kitchel, 2014). A second reason for the design process is ensuring that MEAs are developed in ways that effectively adhere to the principles. This process ensures quality across developers and has a broader impact. As more scholars aim to develop MEAs, they might use this process as a way to ground their MEA design. The development of an MEA can be complex and dynamic, especially when contextualized to local relevance and culturally relevant for students. A collaborative team of experts and skills practitioners helps provide clarity and alignment when following the design process. An outcome from this study is a process that others, who are new to the process, may be able to replicate and develop MEAs that draw upon AgS contexts.

A secondary implication for sharing the design features of creating AgS MEAs is a tool that others can use to contextualize and integrate AgS content into mathematics education. AgS content is important and connected to science, mathematics, and technology content (Ryu et al., 2018) and found in standards for agricultural literacy (AITC, 2014). The MEAs developed using this process were piloted with students during an academic year. A robust description of students' outcomes after engaging in the MEAs is beyond the scope of this manuscript; however, a general finding was that students were able to explore mathematics content while engaging in AgS content that was germane to their lives (Knobloch et al., 2007).

This design process has the potential to guide other scholars' work on MEAs and integrate AgS content into students' classroom learning experiences. The AgS MEAs constructed as part of the research described in this study were constructed to have learning objectives related to AgS concepts in tandem with other CCSSI standards. This research study generated several design features to consider when developing AgS MEAs. It provides a roadmap that may inform others working across education, STEM content, and mathematics and science education areas. We recognize one limitation of this study is uncertainty in whether this process might work for MEAs that are not grounded in AgS content and suggest further research exploring this idea in parallel fields.

One area of future research is communicating a narrative about AgS MEAs from task design to task implementation. This work will fill a gap characterizing AgS MEAs, including similarities and differences from many of the published MEAs. Developing these MEAs is intended to be part of a yearlong implementation project where students are engaged throughout the year. The second area for future research explores students' outcomes from engaging in these AgS MEAs during an academic year. It is unknown whether engagement in these AgS MEAs might influence students' perspectives about AgS content, STEM learning outcomes, STEM career choices, and making connections to their communities and families. While these MEAs were implemented with students, a focus on students' outcomes is beyond the present manuscript's scope. The third area for future research is to test the design process suggested in this research study with MEAs unrelated to AgS. Similar or different findings are revealed when developing MEAs, which can only be noticed when the research moves from exploratory research to design and development research, which seeks to test and revise ideas. Thus, one idea is to apply the design features from this study to designing other MEAs and revising the framework where appropriate.

2.8 Limitations

There are two limitations associated with study one. The first limitation is that an academic expert's perspective on equitable teaching and learning was brought into the design process later than desired. The academic experts associated with the design/development of the AgS MEAs were an expert in culturally relevant pedagogy and literacy practices; however, did not have a background in equitable STEM education teaching and learning practices. Equitable teaching and learning practices are important within mathematics instruction (National Council of Teachers of Mathematics, 2014). The second limitation is this study was a case study. The design process for the study is particular to creating AgS MEAs. The design process is a framework that others may follow when creating content associated MEAs; however, more research must be explored.

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CHAPTER 3. IDENTIFICATION OF ESSENTIAL IMPLEMENTATION COMPONENTS OF AN INTEGRATED STEM CURRICULUM

A version of this chapter was submitted for publication in the Journal of Agricultural Education.

Clark, Q. M., Capobianco, B. M., & Esters, L. T. (in review). Identification of Essential Implementation Components of Integrated STEM Curriculum.

3.1 Abstract

Measuring the factors affecting the implementation process are critical for understanding how, why, and under what circumstances integrated STEM curriculum innovations work. The overarching objective of this National Science Foundation (NSF) funded project was to design, field-test, implement, and evaluate contextualized integrated STEM learning experiences that use agricultural sciences (AgS) as a context. To this end, AgS model eliciting activities (MEAs) were developed. MEAs are thought-revealing tasks that require student teams to mathematize real-world situations. The present study employed the engineering design process guided by the innovation implementation framework to identify essential structural and interactional, integrated STEM curriculum implementation components. Common Core State Standards (CCSS), teacher scopes and sequence plans, student readability level, agricultural sciences contexts, culturally relevant pedagogy, and access to STEM mentors were mapped to the curriculum implementations. Drawing on semi-structured teacher interviews (individual and focus group), recorded teacher development sessions, and documented expert consultations, this study provides research-to-practice findings that support the effective implementation of an innovative integrated STEM curriculum for the elementary school level. The engineering design process guided by the innovation implementation framework provided an iterative method to utilize teacher feedback over five AgS MEA implementations. This work may help mitigate the barriers researchers and teachers experience when implementing integrated STEM curriculum innovations. This work may also help teachers implement integrated STEM curriculum innovations in the classroom, with low student engagement and disruptive student behavior.

Keywords: Engineering design, STEM integration, curriculum implementation, elementary school

3.2 Introduction

A problem that contributes to widening the gap between students who pursue a career in science, technology, engineering, and mathematics (STEM) and students who do not is the lack of academic preparation in STEM subjects, specifically at the elementary school level. This problem was confirmed by the National Academies of Sciences, Engineering, and Medicine (NASEM, 2020), which found that roughly 75% of U.S. students are not proficient in STEM subjects such as mathematics and science at the end of 8^{th} grade. Several factors contribute to the success and interest in STEM, especially among elementary school students, such as culturally relevant pedagogy, early exposure to careers in STEM, and community connections to STEM, all of which represent a planned sequence of integrated STEM curriculum (Clark, 2017; Sithole et al., 2017).

Despite a national call for an integrated STEM curriculum in K-12 education, teachers lack opportunities to participate in integrated STEM-related professional development and the design and development of integrated STEM curriculum (National Academy of Engineering, 2009). Without the appropriate support for teachers to learn about implementing an integrated STEM curriculum, teachers will continue to struggle to understand the essential components necessary to implement an integrated STEM curriculum, and consequently, enhance students' engagement and interest in STEM.

Identifying essential implementation components of curriculum innovations is pertinent to understanding how, why, and under what circumstances curriculum innovations work (Century & Cassata, 2014; Durlak, 2010; Hulleman & Cordray, 2009; O'Donnell, 2008; Ruiz-Primo, 2006; Sanetti & Kratochwill, 2009). Researchers acknowledge that implementing curriculum innovations is complex and includes enacting interrelated components if the implementation outcomes are fully understood. For example, Domitrovich et al. (2008) defined *implementation components* as "a set of features or practices that are directly related to the underlying theory of the intervention" (p. 8). Relating implementation components to an underlying theory of curriculum innovation, researchers can then operationally define implementation components according to their essential parts that lead to intended outcomes (Century & Cassata, 2014). Implementation components, referred to as building blocks, include critical program dimensions, model dimensions, fidelity criteria, essential characteristics, and integral parts (Mowbray et al., 2003; Wang et al., 2020). For this study, critical program dimensions are referred to as essential implementation components. Researchers appear to agree that implementing curriculum innovations increasingly consists of crucial components that must be specifically described and measured to determine which bolster or hinder student performance (Fullan, 1983; Ruiz-Primo, 2006; Wang et al., 2020). However, few studies have identified or explored essential implementation components of curriculum innovations (Levy et al., 2008; Mowbray et al., 2003).

The engineering design process (National Academies of Sciences, Engineering, & Medicine, 2020; Parker et al., 2016) guided by the innovation implementation framework (Century & Cassata, 2014; Gale et al., 2020) is used in this study to identify essential implementation components. The method of identifying implementation components involves iterative curriculum revisions and modifications. – a quintessential characteristic of engineering design. Based on the iterative nature of design, we recognized and fully identified essential implementation components within the innovation implementation framework.

This study's primary purpose was to identify and characterize the structural and interactional implementation components of an integrated STEM curriculum innovation (i.e., agricultural sciences (AgS) model eliciting activities (MEAs). The two research questions that guided this study included the following: (1) What are the structural and interactional components of an integrated STEM curriculum (i.e., agricultural sciences model eliciting activities (AgS MEAs)?, and (2) How was the engineering design process utilized to identify revisions and modifications to an integrated STEM curriculum (i.e., agricultural sciences model eliciting activities (AgS MEAs)?

3.3 Background

3.3.1 Model Eliciting Activities (MEAs)

MEAs are realistic, client-driven problems that are inherently interdisciplinary and require student teams to develop a mathematical model to solve a given situation (Diefes-Dux et al., 2008; Lesh & Doerr, 2003). Using data in real-world contexts, MEAs facilitate learning by developing students' conceptual understandings and sense-making. Model eliciting activities require students to mathematize (e.g., quantify) information in context to develop a mathematical model as a procedure/product (Diefes-Dux et al., 2008). Model eliciting activities are thought-revealing in that they provide student teams an opportunity to self-reflect and provide teachers a window into students' thinking during problem solution development. Six principles guide the design of MEAs

(Diefes-Dux et al., 2008). These design principles require that all MEAs include: (1) model construction – a mathematical model of a procedure/product; (2) realistic context – an authentic STEM-related problem; (3) self-assessment – an opportunity for student teams to self-assess the usefulness of the model; (4) model documentation – a procedure/product description; (5) model shareable and reusable – shareable and reusable for similar purposes; and (6) a useful learning prototype – a globally generalizable or modifiable procedure/prototype. These principles, developed by mathematics education researchers for middle school classrooms (Diefes-Dux et al., 2008), were adapted for first-year college engineering courses and held promise for the instruction of other math and science-rich contexts. MEAs are promoted as a tool primarily limited to researchers and practitioners using them to investigate upper K-12 and first-year college students' learning, thinking, and assessment (Hamilton et al., 2008; Lesh & Doerr, 2003). However, MEAs are also used to diagnose and identify highly gifted and creative students (Chamberlin & Moon, 2005; Hamilton et al., 2008) and as a tool to encourage students to solve real-world problems with mathematical models (Hamilton et al., 2008). Also, MEAs were previously used by education researchers to explore how students think (Leash & Doerr, 2003). The MEAs discussed in this study used AgS contexts to help promote contextualized learning, conceptual understanding and encourage students to consider STEM as a career option by exploring culturally relevant real-world problems.

The AgS MEAs were unique because they were culturally relevant to students' environments and focused on four significant societal challenges (health, energy, environment, and food; Bostic et al., 2020). The AgS MEAs in this study were connected to local urban community issues and relevant across varying cultural groups. AgS MEAs require students to reflect on their situations and make connections between food insecurity versus food security, health, and diet in the context of childhood obesity, the affordance of renewable energy, and equitable access to green spaces.

3.3.2 Agricultural Sciences (AgS) Contexts

AgS (i.e., health, energy, environment, and food) are interdisciplinary areas that have primarily been underexplored (Mercier, 2015) as contexts for integrated STEM curriculum innovations in elementary school settings. Producing foods, fuels, medicines, materials, and the like through agriculture involves various STEM disciplines, including physical sciences, chemical sciences, biological sciences, technology, engineering, and mathematics. Unlike most other fields, which are narrowly defined, agriculture is multidisciplinary, interdisciplinary, and transdisciplinary (Vasquez et al., 2013). Furthermore, the challenges of meeting sustainable clean water, food, medicine, urban green infrastructure, and clean energy needs for over 9 billion people by 2050 situates AgS as an ideal context to explore real-world engineering-based rich problems that are culturally relevant (Wise, 2013).

As a result of several educational reform efforts that emphasized STEM education (Hilby et al., 2014; Phipps et al., 2008), there are multiple calls for agricultural education to prepare students for STEM careers. For example, the National Research Council's (2009) report on *A New Biology for the 21st Century* called for students to prepare for mathematics and science careers through agricultural education. Shinn et al.'s (2003) white paper also outlined agricultural education's role in enhancing students' mathematics performance. Additionally, the American Association for Agricultural Education's National Research Agenda for 2016-2020 listed a research priority to investigate "effective STEM integration models in a school-based agricultural education curriculum" (Stripling & Ricketts, 2016, p. 32). Moreover, the National Research Council (2009) stated that "we are in an era of scientific agriculture that combines basic and applied aspects of the traditional STEM disciplines" (Dossett et al., 2019, p. 256). Hence, this study attempted to answer agricultural education calls to prepare students for STEM careers by implementing an integrated STEM curriculum that used agricultural sciences contexts.

3.4 Frameworks

This study draws upon two complementary frameworks: (1) the engineering design process and (2) the innovation implementation framework. Based on the iterative and cyclical nature of design, we recognized and examined the interactive nature of various components of our efforts to integrate AgS MEAs as a curriculum innovation to improve students' interest and engagement in STEM. What follows is an overview of each framework.

3.4.1 Engineering Design Process

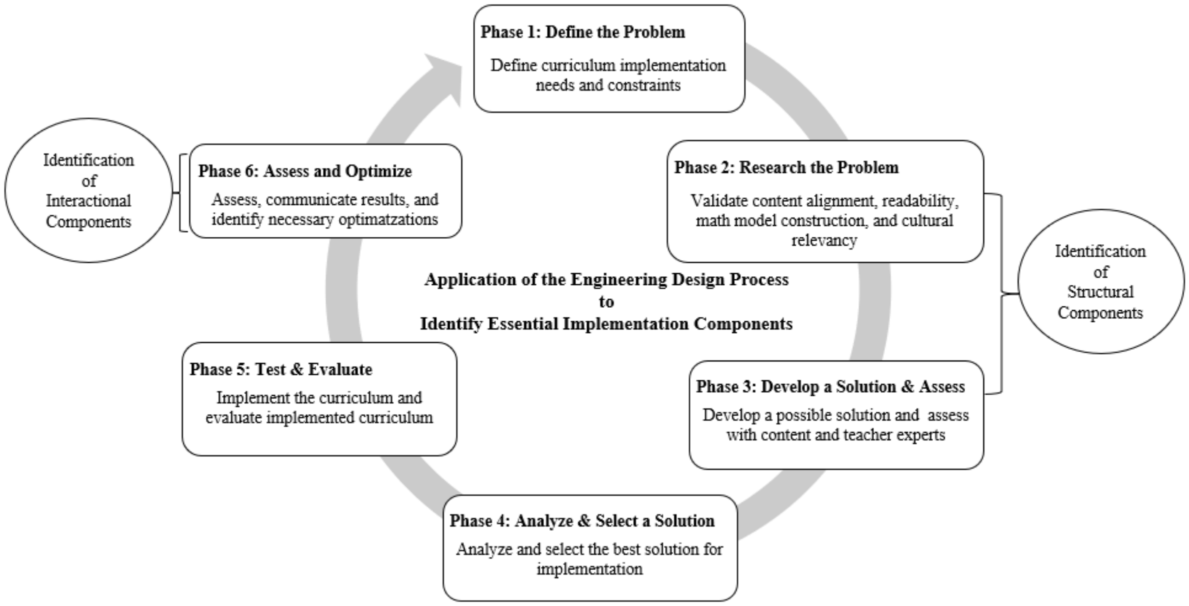
The engineering design process is a systemic cyclical approach to a problem-solving method used by engineers for a design problem (National Academies of Sciences, Engineering, &

Medicine, 2020; Parker et al., 2016). The engineering design process is an iterative process that guides engineers by solving problems and learning important information about the issue and possible solutions to the problem-solving process (Atman et al., 2007; Atman et al., 2005). While the term, engineering design, may vary in different educational domains, common to all definitions of the engineering design process is the iteration of multiple design phases (Capobianco, 2011; Moore et al., 2013; Parker et al., 2016). Because solving a design problem is a contingent process subject to unforeseen complications, the engineering design process's iterative nature is particularly significant.

As defined by the National Academies of Sciences, Engineering, and Medicine (2020), engineering design was characterized using phases (Atman et al., 2007; Atman et al., 2005). The first phase is to determine the problem. Defining the problem involves moving from a vague, abstract idea of a design problem to a clear, unambiguous definition of the problem. A more explicit problem definition statement will evolve as a complete understanding of the design problem's human needs and constraints are understood. The second phase is researching the situation. Gathering pertinent information about the design problem can reveal facts about the situation that can validate or redefine the design problem statement through a series of questions asked and answered. The third phase is developing possible solutions to the design problem. Developing possible solutions involves generating creative new ideas that may solve the specified human needs and constraints. The fourth phase is analyzing and selecting a problem solution. Possible solutions are analyzed and vetted with experts during this phase, whereby the best solution is chosen for implementation. Lastly, phase five is to test and evaluate. The first part of phase five, testing and implementation, involves creating a fully operational prototype of the solution, then tested during implementation. The second part of phase five, evaluation, requires an assessment of the implementation. During phase five, design decision-making and communication are essential to developing quality solutions. Different design problems may require a slightly different version of the engineering design process. The five primary phases describe an iterative, cyclical approach common to most applications of the engineering design process and enable engineers to continually enhance and improve their designs through repeated testing, analysis, and re-design (Atman et al., 2007; Atman et al., 2005).

This study operationalized the engineering design phases in the following ways. Phase one defines the problem by defining the integrated AgS MEA curriculum implementation needs and constraints. During phase one, the issue was to move the curriculum implementation from a vague, abstract concept to a clear, unambiguous plan that ensured fidelity of implementation. Fidelity of implementation is the "extent to which an enacted program is consistent with the intended program model" (Century et al., 2012, p. 347; O'Donnell, 2008). Phase two, researching the problem, was accomplished by gathering and validating information about the AgS MEA curriculum implementation to ensure program consistency. Collecting and validating alignment of the AgS MEA content with Common Core State Standards Initiative (2010), content readability level, mathematical model construction and content, and cultural relevancy were pertinent to ensuring implementation's fidelity. Phase three, developing possible solutions, was achieved by assessing the AgS MEA curriculum implementation content during teacher development sessions with participating teachers of the AgS curriculum implementation. Phases two and three identified essential structural implementation components. Phase four analyzed and selected a solution for implementation through a vetting session with content experts. Phase five tested and evaluated the implementation of the AgS MEA curriculum. For this study, it was necessary to add a sixth phase, assess and optimize, to the engineering design process. During phase six, the AgS MEAs are assessed for necessary optimization.

After each of the five AgS MEA implementations, teacher focus groups captured teachers' feedback about what worked and did not work. The assessment part of phase six identified essential interactional implementation components and implementation revisions and modifications, thereby enabling the continual enhancement and improvement to the next AgS MEA implementation through the iterative engineering design process express-test-re-design. Figure 3.1, Application of the Engineering Design Process to Identify Essential Implementation Components, illustrates how this study operationalized the engineering design phases. Figure 3.1 also shows at what phase of the engineering design process essential innovation implementation components (structural and interactional) were identified.



Note. This model shows that identifying structural components occurred at phases two and three, and identifying interactional components occurred at phase six of the iterative engineering design process.

Figure 3.1. Engineering Design Process to Identify Essential Implementation Components

3.4.2 Innovation Implementation

The innovation implementation framework is defined as "the extent to which [curriculum] implementation components are in use at a particular moment in time" (Century & Cassata, 2014, p. 87). The framework conceptualizes curriculum implementation as complex and composed of essential explicit or implicit components (Century & Cassata, 2014; Gale et al., 2020). The innovation implementation framework identifies and categorizes two significant types of curriculum implementation components: structural and interactional. Structural components include "organizational, design, and supportive elements, which are the building blocks" (Century & Cassata, 2014, p. 88) of the curricular implementation. Structural components are divided into procedural parts (i.e., organization and curriculum design elements) and educative parts (i.e., support elements that communicate what learners need to know). Interactional components include "behaviors, interactions, and user practices during enactment" (Century & Cassata, 2014, p. 88). Interactional components are divided into pedagogical parts (i.e., support actions expected of teachers during curriculum implementation) and learner engagement parts (i.e., support students with expected engagement when partaking in the curriculum intervention).

There are two main propositions of the innovation implementation framework that are relevant to this study. The first assumption is that curriculum implementation components vary in terms of the number and type of components and the degree to which components are either explicit or implicit within an implementation model. The second assumption is that some implementations focus more on structural components and some implementations focus more on interactional components. Century et al. (2012) emphasized that utilizing all identified essential implementation components is not necessarily optimal, noting that appropriate utilization of specified components varies depending on the degree to which these components are explicit or implicit within and across implementations. With that said, the innovation implementation framework was used as a guide to define and categorize the identified structural and interactional implementation components across five implementations. In addition to identifying essential structural and interactional implementation components, researchers in this study sought to identify revisions and modifications to the integrated STEM curriculum. The identified structural and interactional implementation components elicited revisions and modifications to the STEM integrated curriculum implementation during each of the five iterative implementation cycles. Revisions and modifications were made and substantiated by the explicit and implicit role the identified implementation components played within and across each implementation.

There is a broad consensus that the implementation of curriculum implementation rarely occurs as intended. Implementation of curriculum innovations is complex and includes an understanding of essential components if the implementation outcomes meet the needs of the intended model and are fully understood (Century & Cassata, 2014; Durlak, 2010; Hulleman & Cordray, 2009; O'Donnell, 2008; Ruiz-Primo, 2006; Sanetti & Kratochwill, 2009).

The engineering design process guided this study using the innovation implementation framework to identify and categorize the structural and interactional curriculum implementation components. The study also identifies structural and interactional STEM curriculum implementation components across five implementations and curriculum revisions and modifications.

3.5 Context of the Study

3.5.1 School Setting

This study took place in the central part of the United States (U.S.) at a K-6 environmental magnet school located in a large urban school district. The U.S. Department of Education (2004) defines a magnet school as one that offers a range of distinctive education programs emphasizing math, science, technology, visual and performing arts, or humanities. In the context of this study, the magnet school focused primarily on STEM education. The school comprised an 83% minority population, with 61% of students receiving free or reduced lunch assistance. A mission of the school was to integrate environmental and agricultural sciences into an elementary education curriculum. To help achieve this mission, researchers associated with the project supported the school in preparing for and receiving STEM certification through the Indiana Department of Education (Indiana Department of Education, 2020). The certificate boosted the total number of Indiana STEM Certified schools to seventy-eight. The Department of Education awards an Indiana school with STEM certification based on completing a rigorous application, review, and commitment to teaching STEM disciplines throughout the school year (Indiana Department of Education, 2020).

3.5.2 Participants

A convenience sample of seven elementary school teachers participated in this study for three years. Teacher participants received a stipend and instructional supplies for participating in the study. Participants included four sixth-grade teachers and three fifth-grade teachers, representing six female teachers (one African American, Black, and five Caucasian, White) and one male teacher (Caucasian, White). Years of teaching experience ranged from four to more than 15 years. The teachers' subject expertise areas included English language arts (ELA), mathematics, and science. Of the seven teacher participants, five teachers completed three or more implementations of the MEAs. Table 3.1 summarizes the teacher participants.

Table 3.1. Description of Teacher Participants and the AgS MEA Curriculum Implemented

Teacher Name	Grade Level	Subject Expertise	Years of Teaching Experience	AgS MEA Implementations
Montana	6	Science	<15	1, 2, 3
Tina	6	ELA	>5	1, 2
Maria	6	ELA	<15	3, 4, 5
Windy	6	Science	>5	3, 4, 5
Carol	5	Mathematics	>5	1
Sam	5	Mathematics	>5	2, 3, 4, 5
Christine	5	ELA	<10	1, 2, 3, 4, 5

Note. Pseudonyms are used to protect the anonymity of the participants.

3.5.3 Teacher Development

The goals of the teacher development sessions were to: (a) conduct an explanatory demonstration of the AgS MEA; (b) engage teachers in a reflective discussion about any immediate implementation concerns; and (c) engage teachers in conversations about culturally relevant pedagogy, community engagement, and STEM career exploration. Before each implementation, teacher participants attended 45-minute professional development sessions for five sessions over three years. Throughout the professional development, teachers provided continuous feedback on the development and refinement of each AgS MEA. This feedback served a dual purpose: (1) informed the team about the effectiveness of the professional development, and (2) provided rich data from the teacher participants about their ideas and understanding related to implementing MEAs.

3.5.4 Agricultural Sciences (AgS) Model Eliciting Activities (MEAs)

Five AgS MEAs were introduced to the teachers over three school years. Each AgS MEA addressed a major societal challenge: (1) health and human diet; (2) renewable energy; (3) urban green spaces, and (4) food security and insecurity (see Table 3.2). To ensure cultural, career, and community connections to students' real-life experiences, each AgS MEA was connected to a relatable topic – a societal challenge related to local community issues, STEM careers, and culturally relevant. All AgS MEAs were developed to adhere to the models and modeling perspective and associative principles (Bostic et al., 2020; Lesh & Doerr, 2003) and were aligned with national standards (CCSS, 2010) (See Table 3.2).

Table 3.2. Five AgS MEAs and Corresponding Features

AgS MEA Title	Societal Challenge	AgS Learning Context	Problem Statement Key Question	Example of Common Core State Standards Potential Addressed
Healthy Food Choices	Health	Public health & nutrition related to childhood obesity	How do consumers use the Nutrition Facts Label information to make healthy food choices?	CCSS.MATH.CONTENT.5.OA.A.2 Write simple expressions that record calculations; interpret numerical expressions without evaluating them.
Renewable Energy	Energy	Sustainable energy (wind, solar, & energy)	What are the ways we can harness renewable energy for use in our everyday life?	CCSS.MATH.CONTENT.5.NBT.B.7 Add, subtract, multiply, and divide decimals to hundredths, using concrete models or drawings and strategies based on place value, properties of operations.
Urban Green Spaces 2.0	Environment	Equitable urban green space development	How do design and access to green spaces influence the quality of life for residents in urban neighborhoods?	CCSS.MATH.CONTENT.4.G.A.1 Draw points, lines, line segments, rays, angles (right, acute, obtuse), and perpendicular and parallel lines. Identify these in two-dimensional figures.
Food Security/ Insecurity	Food	Urban community gardens	How can a community contribute to increasing the availability of healthy food?	CCSS.MATH.CONTENT.4.OA.A.3 Solve multistep word problems posed with whole numbers and having whole-number answers using the four operations.
Healthy Food Choices 2.0	Health	Public health & nutrition related to childhood obesity	How do consumers use the Nutrition Facts Label information to make healthy food choices?	CCSS.MATH.CONTENT.5.OA.A.2 Write simple expressions that record calculations with numbers and interpret numerical expressions without evaluating them.

Note. The reference of 2.0 after an AgS MEA title refers to an updated version.

3.6 Methods

This study utilized a qualitative case study (Merriam & Tisdell, 2015; Yin, 2017) approach, wherein five implementations of AgS MEAs by teacher participants represented the case. The case study design allowed for investigating a contemporary phenomenon such as integrated STEM AgS MEA curriculum innovations (the case) in its real-world context (the classroom). This case study focused on integrated STEM curriculum implementation by individual classroom teachers. A case in this study was identified by the implementation of the MEA rather than the individual teacher.

The study aimed to identify essential implementation components. Hence, the actual implementation of the AgS MEAs was the primary focus and unit of analysis in our work. The implementation of five AgS MEAs was examined to identify structural and interactional implementation components and identified revisions and modifications for implementing the integrated STEM curriculum. The case study was bounded by a finite time for interviews and a defined number of teacher participants available for interviews.

3.6.1 Data Sources

This study employed semi-structured teacher interviews (individual and focus group), recorded teacher development sessions, and documented expert consultations as data sources. Data sources were used to identify the structural and interactional implementation components of the AgS MEAs and identify revisions modifications for viable implementation of the AgS MEAs. Semi-structured interviews are important sources of case study evidence (Yin, 2017). Semi-structured interview protocols allowed data to be collected using different modalities, such as making keen visual and aural observational field notes while collecting audio and video recordings. Data were gathered at two separate timeframes. The first timeframe occurred during phase three (Develop a Solution & Assess) of applying the engineering design process. During phase three, teacher development and content expert consultations focused on identifying structural implementation components and any revisions and modifications for viable implementation of the AgS MEAs. The second timeframe occurred during phase six (Assess and Improve) of applying the engineering design process. Teacher focus groups and content expert consultations focused on identifying interactional components and revisions and modification for viable implementation of the AgS MEAs. Each interview type (i.e., teacher's professional development, teacher focus groups, and content expert consultations) is described below.

3.6.2 Teacher Development

Teacher development sessions engaged teachers in discussion with the researcher about structural components of the AgS MEA implementation. Recall that structural components include procedural elements such as organization and curriculum design and educative support elements that communicate what learners need to know about the AgS MEA implementation. A prototype of the AgS MEA was emailed to teachers one week before the teacher development session. Sessions were held for 45-minutes and were guided by a semi-structured interview protocol to resemble a guided conversation. A structured Q&A protocol was avoided to ensure that teachers could freely discuss and identify structural implementation components that were grade-appropriate and conform to students' classroom environments. The teacher development sessions began with an open-ended question (e.g., "Do you have any questions about the AgS MEA implementation?") and prompted teachers to openly discuss the AgS MEA implementation with critical questions and feedback on the AgS MEA implementation. We then asked teachers a series of semi-structured questions focused on structural components such as AgS MEA curriculum support material, culturally relevant meaningful engagement methods, team formation, supportive technology, AgS MEA assessment, and the general implementation plan.

3.6.3 Teacher Focus Groups

Teacher focus groups engaged teachers in discussing the interactional components of the AgS MEA implementations. The interactional AgS MEA implementation components include pedagogical elements such as behaviors, interactions, users' practices during implementation, and learner engagement elements that engage students through community partners, culturally relevant data sources, guided reflections, supportive technology, and team roles & responsibilities. Teacher focus groups were conducted one day post-AgS MEA implementation, inclusive of the second data collection. Focus groups were held for 45-minutes and were guided by a semi-structured interview protocol to resemble a guided conversation. A structured Q&A protocol was avoided to ensure that teachers could openly discuss and assess the AgS MEA implementation, identify interactional implementation components, and identify AgS MEA revisions and modifications to inform subsequent AgS MEA implementation. The five AgS MEA post-implementation focus groups began with a semi-structured protocol consisted of six open-ended questions. Iterative refinements were made to the list of items comprising the post-implementation semi-structured protocol after each AgS implementation. Sample questions from the semi-structured protocol were: "What went well during the AgS MEA implementation? What did not go well? Describe the effectiveness of the AgS MEA implementation; for example, what areas or components of the AgS MEA need improvement?" "What were additional supports that you felt you could have used?" "How did team roles and responsibilities support MEA implementation?"

3.6.4 Content Expert Consultations

Documented content expert consultations provided specialized input on the AgS MEA implementations after the first and second data collection timeframes. Content experts included three faculty members from three different research-intensive universities and three K-12 teachers. The university faculty had expert knowledge in agricultural sciences, mathematics, and applied sciences. The three K-12 teachers had expertise in science, mathematics, and culturally relevant education. The K-12 teachers were licensed and received MEA implementation professional development (~80 hours). Content experts were emailed an AgS MEA prototype before and after each of the five AgS MEA implementations. Semi-structured questions to resemble an AgS MEA implementation assessment rubric guided the content experts' consultations. Two sample semi-structured questions were, "To what degree does the AgS MEA support all learners' engagement in the MEA?" "What challenges do you perceive with implementing this MEA as part of your classroom instruction?" (Bostic et al., 2020).

3.6.5 Data Analysis

All recordings of data were transcribed verbatim. The three members of the research team cleaned the transcripts by making corrections while listening to the recordings. Data analysis involved a four-step process. First, data from teacher development sessions, teacher focus groups, and content expert consultations from all five AgS implementations were analyzed using a constant comparative method. The constant comparative data analysis method extracts information from data collected then compares information to emerging categories (Creswell, 2014; Merriam & Tisdell, 2015). Second, data were systematically archived in two data time frames, which occurred during phases three and six of the iterative engineering design process. Phase three of the engineering design process involved collecting data from teacher development sessions and content expert consultations, which informed structural AgS MEA implementation components. Phase six of the engineering design process reported interactional AgS MEA implementation components. Phases three and six of the engineering design process informed revisions and modifications for viable implementation of the AgS MEAs. Third, data were coded using an open coding method (Creswell, 2014; Merriam & Tisdell, 2015). Open coding refers to a process of reading through transcripts while jotting down notes and observations in the margins while remaining open to bits of data that may be potentially relevant or important to the study (Merriam & Tisdell, 2015). Open coding allowed for major implementation components to emerge from the data, triangulating the three data sources. Finally, the researcher employed a detailed line-by-line member check of data to generate final thematic categories, verify relationships among categories, and describe each category. Revisions and modifications identified for viable implementation of the AgS MEAs emerged during each iterative data analysis.

3.6.6 Validity and Reliability

The researchers used member checking to ensure the transcripts captured the conversations correctly and represented teacher participants accurately. As recommended by Yin (2017), several strategies used assessed validity and reliability. Construct validity was accomplished through multiple data sources to establish a convergence of evidence (i.e., teacher development sessions, teacher focus groups, and content expert consultations). Internal validity was accomplished through the triangulation of all three sources and independent researcher member checking. External validity was achieved through the iterative engineering design process to ensure replication logic among the five AgS MEA implementations; specifically, researchers sought literal replication among the five implementations (Yin, 2017).

3.7 Findings

3.7.1 AgS MEA Structural Components

Structural components support procedural elements and communicate what learners need to know. Structural components inform the ways that teachers implement the AgS MEAs. Through teacher development sessions, teacher focus groups, and documented expert consultations, six recurring structural AgS MEA components were identified, which led to the revisions and modifications necessary for the viable implementation of the AgS MEA curriculum. The first structural component, the *cover page*, described the idea of introductory information. The second structural component, the *advanced organizer*, supported topic-related content. The third structural component, *discussion topics,* supported the concept of topic-related discussions and culturally relevant content. The fourth structural component, *problem-solving strategies*, supported a structured method of communicating the problem to solve. The fifth structural component, the *MEA assessment rubric*, provided a way to assess the student team's final solution presentation. The sixth structural component, the *implementation plan*, supported a process to ensure implementation consistency.

What follows is a description of each of the six structural AgS MEA implementation components derived from data and any revisions and modifications made to the AgS MEA implementation process for viable AgS MEA implementation. Table 3.3 outlines the six structural AgS MEA components.

3.7.2 Cover Page

Teachers in this study discussed concerns for having a guiding document that would briefly introduce the AgS MEA's learning goals and supplies needed. Teachers' comments included the following: "What is the goal of the AgS MEA?" How do we know what supplies will need for the final AgS MEA presentation?" "What state standards do the AgS MEA address?" Structural component one, the *cover page*, addressed teachers' concerns by functioning as a one-page introduction to the AgS MEA. Each AgS MEA *cover page* included the AgS MEA title, fundamental question, student learning goals, a list of guiding documents to help teachers align the AgS MEA with state standards, information about team formations, and recommended supplies. The cover page also served as a reminder of best practices (i.e., team formation for essential cooperative learning experiences). The cover page revisions and modifications included refining information about team formation, learning outcomes, and recommended supplies. See Appendices E-K for examples of an AgS MEA *cover page*.

3.7.3 Advanced Organizer

Teachers in this study expressed the effectiveness of utilizing a news article. Examples of teachers' comments included the following: "I thought, beginning with the news article helped with drawing the kids in." "Yeah, they thought about the news article throughout the AgS MEA." "I think to a certain degree; students could relate their home experiences to the news articles."

Structural component two, the *news article*, functioned as an advanced organizer. News articles included AgS MEA related-content reading based on local current events, culturally relevant data-driven material, websites of reference material, informational images, technical terms, and thought-provoking discussion prompts. Revisions and modifications made to support viable implementation included guided discussion prompts, which were instrumental in tandem with the advanced organizer's principles by engaging student teams in topic-related discussions. See Appendices E-K for examples of an AgS MEA *advanced organizer/news article*.

3.7.4 Discussion Topics

In this study, teachers expressed concerns about the layout of questions and answers designed to assess students' knowledge from reading the news article. Teachers commented that "the readiness questions and answers do not appear to connect students to the news article or the problem to solve." "How can we incorporate culturally relevant content into the news article?" "If you are not a teacher who is familiar with stimulating classroom discussion or preparing kids for discussion, then things may not go well." Structural component three, *discussion topics,* functioned as a guided topic-related discussion. Through guided discussions, teachers could better assess students' comprehension of subject matter and the related STEM context. Discussion topics also supported teachers with engaging students to organize their thoughts for problem-solving. The discussion topics were instrumental in providing a culturally relevant context with supported data sets. Revisions and modifications made to support viable implementation included removing questions and answers and inserting discussion topics and culturally relevant data charts. See Appendices E-K for examples of how *discussion topics are facilitated in the AgS MEAs*.

3.7.5 Problem-Solving Strategies

Teachers in this study expressed concerns about students' not understanding where to begin solving the problem or what steps to take when solving a problem. Teachers commented, "My students were unsure what steps to take in solving the problem." "Students did not have any concept of what they were supposed to look for in the problem statement." "There could have been more structure in like deciding the outcome of what the students were going to solve." Structural component four, *problem-solving strategies*, provided students with strategies or steps to solving the problem. Problem-solving strategies or actions supported teachers in helping students get started with solving the problem and getting unstuck. Problem-solving strategies also serve as a motivation to decrease anxiety associated with solving a problem. Problem-solving strategies were instrumental in encouraging both teachers and students to define and explore the problem. Revisions and modifications made to support viable implementation included problem-solving strategies or steps to the problem statement. The problem statement, presented in a memo form, addressed students from a client, where the client asked students to solve a real-world problem. See Appendices E-K for examples of AgS MEA problems solving strategies.

3.7.6 MEA Assessment Rubric

In this study, teachers requested a means for assessing students' problem-solving skills, mathematical model construction, content comprehension, and overall final solution presentation skills. Teachers' comments included the following: "How can we assess if students are comprehending the MEA content?" "We have no idea how to assess students' final presentations" Should we assess students individually or as a team?" Structural component five, the *MEA assessment rubric*, functioned as a means for teachers to evaluate the quality of the student team's final presentations, including teamwork, mathematical model construction, and MEA content knowledge. The assessment rubric provided teachers with a specific set of criteria to assess students' performance with the AgS MEA. The assessment rubric reduced teachers grading time, conveyed timely feedback to students, and significantly improved students' ability to address and include required elements of their final solution presentation. The assessment rubric was instrumental in providing teachers with meaningful insight into students' skill development, mathematical modeling, STEM content comprehension, presentation skills (i.e., voice, graphs, tables, words), and overall teamwork. Revisions and modifications made to support viable implementation were the design and use of an assessment rubric that included criteria, performance levels, scores, and descriptors, which could easily be modified for each of the five AgS MEA implementations. See Appendix L for an example of an AgS MEA assessment rubric.

3.7.7 Implementation Plan

Teachers in this study expressed concerns about implementing the AgS MEAs without a guide that would facilitate fidelity of implementation. Teachers stated the following: "Figuring out how much time it takes to teach each part of the MEA and organize community partner visits is confusing." "I'd like to have a plan for instruction." "How will we know if we are implementing the MEA according to Purdue's expectations?" Structural component six, the *implementation plan* functioned to guide the extent to which implementation fidelity is present, ensuring that the newly implemented curriculum program is consistent with the intended program model. Using the AgS MEA implementation plan, teachers were better able to plan their instruction for each task of the MEA, determine any materials required, and prepare for classroom visits from STEM professionals. The implementation plan also supported a smooth and timely implementation by outlining implementation procedures, which encouraged students to add flex-days into the schedule and allowing extra time to complete the MEA. The implementation plan was instrumental in automating the process of implementing the five AgS MEAs. Revisions and modifications made to support viable implementation included designing and implementing an implementation plan that helped implement fidelity. See Appendix M for an example of an AgS MEA implementation plan.

Table 3.3. Structural AgS MEA Implementation Components

AgS MEA Components	Type	Description
Cover Page	S	The cover page served as an introduction to the AgS MEA to cover critical questions, learning goals, guiding documents, and recommended supplies.
Advanced Organizer	S	The news article served as topic-related content reading based on local current events and research to introduce the AgS problem.
Discussion Topics	S	Discussion topics serve as a method to engage students in topic-related discussions.
Problem-solving Strategies	S	Problem-solving strategies provided students with support to solve the problem.
MEA Assessment Rubric	S	The MEA rubric consists of measures to assess the quality of the student team's final presentations on team formation, cooperative learning, and mathematical model construction.
Implementation Plan	S	The implementation plan functioned as a measure to guide the extent to which implementation fidelity ensured that the newly implemented curriculum program is consistent with the intended program model.

Note. S = Structural.

3.7.8 AgS MEA Interactional Components

Interactional components support teachers' and students' behaviors, interactions, and practices during implementation. Interactional components were divided into two pedagogical parts (i.e., support actions expected of teachers during curriculum implementation) and learner engagement parts (i.e., support students with expected engagement when partaking in the curriculum intervention). Through teacher development sessions, teacher focus groups, and documented expert consultations, six recurring interactional AgS MEA components were identified, which led to the revisions and modifications necessary for the viable implementation of the AgS MEA curriculum. The first interactional component, *student mentorship*, involved STEM career exploration from university researchers and community industries. The second interactional component, *problem identification,* supported problem scoping, meta-cognition, and self-regulated learning. The third interactional component, *culturally relevant pedagogy*, facilitated cognitive development through relevant and relatable contexts that reflected students' diverse backgrounds. The fourth interactional component, *team roles, and responsibilities* promoted team participation through interdependence, structured team assignments, and student accountability. The fifth interactional component, *reflection prompts* supported group, and individual thought. The sixth interactional component, *supportive technology,* promoted enhanced learning, teaching, and assessment strategies.

The sections below describe each of the six interactional AgS MEA implementation components derived from data and any revisions and modifications made to the AgS MEA implementation process for viable AgS MEA implementation. Table 3.4 summarizes the six interactional AgS MEA components.

3.7.9 Student Mentorship

Teachers in this study expressed a concern that students were not making strong connections to STEM careers. Teachers shared the following concerns: "My students do not understand how to identify STEM careers. For example, because they have a parent that works at a hospital, they think their parent is a nurse." "I think it would great to see young people who have started college that can answer questions like, why did I select this STEM field, how did I get interested in this filed, or at what point in high school did I start looking at college or what did I need to learn." Interactional component one, *student mentorship,* provided teachers with STEM graduate student mentors, facilitating seamless student connection between the AgS MEA and STEM careers. Student mentorship provided students with practical examples of STEM career applications, career information, and interdisciplinary knowledge about the AgS MEA content. Student mentorship also supported students' better understanding of education. Student mentorship was instrumental in providing students and teachers with an opportunity to meet with STEM professionals. Student mentorship allowed STEM professionals to share their professional journeys from a wide range of STEM fields ranging from civil engineers, nutritional scientists, agriculturalists, food scientists, learning scientists, and city planners. Revisions and modifications made to support viable implementation were creating "*My Career Passport,*" a concept where students completed entries in their *Career Passport,* a small booklet to include their name, hobbies, and future career aspirations. Students also completed entries about six different STEM professionals. The entries included information about the STEM professional's name, STEM career, and favorite part of their job. See Appendix N for an example page of *My Career Passport*.

3.7.10 Problem Identification

In this study, teacher's expressed concerns about students' understanding of the problem statement objective. Teachers' comments included the following: "Maybe students could use a little more background knowledge." "Some students had no idea what the task was." Interactional component two, *problem identification,* provided teachers with criteria to help students define the problem. Through a group or self-reflection, students answered questions about the problem. Problem identification supported teachers in following a problem-solving strategy that supported students understanding of the problem to solve. Problem identification also provided students and teachers a method to work through getting stuck when solving a problem. Problem identification was instrumental in providing teachers and students with a structured process for understanding the problem knowns, unknowns, and how to draw figures that show fundamental relationships. See Appendices E-K for an example of *problem identification* criteria.

3.7.11 Culturally Relevant Pedagogy

The teachers expressed concerns about how to connect the AgS MEA content to students' lived experiences. Examples of teachers' responses including the following: "I think it would be interesting or beneficial if we could somehow incorporate the problem into students' lives;" "One idea is to have students track relevant daily life activities;" and "Students' struggled with the problem because it was not a part of their 11- and 12-year-old reality." Interactional component three, *culturally relevant pedagogy,* referred to data sets that reflected students' daily lived experiences, reflecting students' diverse backgrounds. Culturally relevant pedagogy supported teachers with a better understanding of how to enact culturally relevant teaching practices, understand the pedagogical connections between culturally relevant teaching, meaningful student engagement, community engagement, and STEM career exploration. Culturally relevant pedagogy engaged teachers and students in STEM outside of the classroom and enabled students to experience real-world agricultural sciences applications. Culturally relevant data was instrumental in facilitating cultural competence and critical consciousness among teachers and students. See Appendices E-K for an example CRP used with the AgS MEA content.

3.7.12 Teams Roles and Responsibilities

Teachers shared concerns about students' team formation and lack of cooperative learning experiences and nonparticipation by some students. Teachers' comments included: "I had kids that were doing nothing, absolutely nothing. They were not trying; they had no idea how to do the math." "They took the roles and responsibilities seriously – it was an accountability system." "I was surprised that students remembered what their role was, and they seemed to understand." "Giving roles and responsibilities to each team member gave ownership to students." Component four, *team roles and responsibilities*, supported essential elements of practical cooperative learning experiences and eliminating nonparticipation. Team roles and responsibilities established individual accountability for a specific task on a team. Team roles and responsibilities also created an interdependence – the team could only complete the AgS MEA if all team members performed their team responsibilities. Team roles and responsibilities were instrumental in creating a robust cooperative and competitive nature among student teams. See Appendices E-K for *team roles and responsibility chart*.

3.7.13 Reflection

Teachers in this study were concerned that due to students' lack of experience with cooperative learning, some students were engaged in "off-task" activities and had no self-regulation skills. Teachers shared the following insights: "Students continue to engage in off-task behaviors during the implementation period." "I think the reflections and thinking about thinking will help the student to reflect on what they've learned comprehend what is happening as opposed to trying just to write it down." Reflection helps students remain on task." Component five, *reflection,* prompted students' thinking and learning (Andresen, 2008; Blomhøj, 2008). Reflection motivated students to define, explore, and plan. Reflection also conditioned students to self-regulate their learning (Andresen, 2008; Blomhøj, 2008). The reflections provided teachers time during implementation to do individual student check-ins and review student reflections. Reflections also supported the development of metacognitive skills and strategies to solve a problem by monitoring one's comprehension, self-assessing, and self-correcting. Reflections were instrumental in providing teachers with a window into how students were individually and a group, conceptualizing the problem to solve. Revisions and modifications made to support viable implementation were added time and space to self-reflect or reflect as a group. See Appendices E-K for an example of AgS MEA *reflection prompts*.

3.7.14 Supportive Technology

Teachers requested supportive technology to assist with AgS MEA background knowledge and final solution presentations. Teachers noted the following suggestions: "Students like the visual stuff." "Supportive videos serve as a great starting point." "Students struggle to understand or visualize certain terms. Using the computer to Google terms is helpful." Students struggle to connect specific STEM careers with the MEA topic." Component six, *supportive technology* enhances students' learning and teaching and assessment instruction strategies. Learning technologies such as Virtual Classroom provided a platform for student teams to collaborate on a project while in the face-to-face classroom. YouTube provided a host of informational videos to assist students with a conceptual understanding of certain concepts. Learning technologies also supported students in the final solution presentation through the use of Google Slides. Learning technologies were instrumental in identifying STEM careers and technical aspects of a STEM career that a student may not have an opportunity to see.

Table 3.4. Interactional AgS MEA Implementation Components

AgS MEA Components	Type	Description
Student Mentorship	I	STEM career and community connections and exploration through the industry, higher education, and local community interaction.
Problem Identification	I	Problem identification criteria supported teachers and students in defining the problem to solve. Prompts enlisted students to list the problem knowns, unknowns, and draw figures that show fundamental relationships.
Culturally Relevant Pedagogy	I	Culturally relevant teaching practices are reflective of student's diverse backgrounds, thereby facilitating connections and relatable contexts.
Team Roles & Responsibilities	I	Team roles and responsibilities promote practical cooperative learning by eliminating nonparticipation through interdependence, structured team assignments, and student accountability.
Reflection	I	Group- or self-reflection promotes teachers' and students' thinking and learning.
Supportive Technology	I	Technological tools used to enhance learning, teaching, and assessment strategies.

Note. I = Interactional.

3.8 Discussion

MEAs, by nature, are contextual pedagogical tasks to teaching and learning that require active learner engagement. With that said, there is no surprise that this study's findings illustrate implementation components that advocate active learning engagement, specifically, the interactional components. The tenets of contextual teaching and learning include self-regulated learning, culturally relevant pedagogy, multiple contexts, authentic assessment, and interdependence (Johnson, 2002; Sears & Hersh, 1998), all of which are represented in the six interactional implementation components. For example, implementation component *team roles and responsibilities* promoted the contextual tenet of cooperative learning through interdependence. After students were assigned *team roles and responsibilities,* teachers reported that student nonparticipation decreased, and student motivation and accountability increased. Another example, implementation component *reflection*, promoted the contextual tenet of self-regulated learning through reflection. Here, students were given a notebook inclusive of thought-provoking questions that guided students through a process of self-observation, self-evaluation, and self-reflection while problem-solving. These metacognitive experiences helped students to develop problem-solving strategies. Lastly, *culturally relevant pedagogy* and *student mentorship* interactional implementation components promoted the contextual tenets of anchoring teaching and learning in students' diverse life and learning in multiple contexts. Research states that the top factors contributing to STEM success and prompt interest in STEM among underrepresented students in K-12 are culturally relevant pedagogy and community connections to STEM through mentorship (Clark, 2017). The AgS MEA content was developed using culturally relevant pedagogy, and students received mentorship to STEM careers through interactions with the local industry and the participating University.

Lastly, active learning engagement is also advocated through structural implementation components such as *advanced organizers.* Ausubel (1960) wrote extensively about *advanced organizers* as critical learning strategies that provide a framework for learning. An *advanced organizer* provides relevant anchoring ideas, organization, clarity of ideas, and distinguishability of new ideas. For example, the *news article* (*advanced organizers*) provided scaffolding for new ideas by presenting introductory material about a relatable topic. Each *news article* underwent a Flesch-Kincaid readability test (Kincaid et al., 1975) to ensure appropriate grade-level readability.

3.9 Limitations

It is important to discuss the limitations of this study. First, this study was limited by the number of teacher participants and classrooms. This study focused on the participation of seven classroom teachers. Although this number may appear low, it is important to revisit the value and purpose of our methodological approach. Despite the ongoing debate about credibility, case study research is an increasingly popular and purposeful approach to conducting qualitative research (Hyett et al., 2014). This approach allowed a degree of flexibility that is not readily offered by other qualitative methods. Our approach to the case study was designed to suit the case (i.e., the five MEA implementations across seven classroom teachers). Emphasis was placed on full implementations across multiple classrooms over several years. Therefore, these implementations constitute a viable sample size. To further generalize our findings, additional teacher participants and classrooms could strengthen the study design. The second limitation is the impact these components may have on student engagement and learning. Based on work generated in the larger project, the AgS MEA implementations produced a significant body of data, including, but not limited to, student artifacts (e.g., final student presentations of the AgS MEA solutions and the AgS MEA workbooks). Analysis of these student artifacts could provide insights into student engagement with each identified essential implementation component. Lastly, the third limitation is the variability across the teacher classrooms. Based on initial observations, it was clear that each classroom experienced different instructional and school-based challenges, including a lack of teacher expertise, low student engagement, and disruptive student behavior. As we continued working with the teacher participants, it was clear that the feedback they provided simultaneously served as the necessary and urgent structures the teachers needed to successfully and productively implement the MEAs. This is a testament to the need for these components for MEA implementation and applying the engineering design process as a systematic method to gather and utilize iterative and constructive teacher feedback. A classroom's context can be a useful lens for understanding how implementation components may influence classroom complexities that may affect teaching and learning. Analyzing how specific implementation components may influence classroom complexities could provide viable insights into enacting pedagogical practices that promote equitable outcomes for students and teachers.

3.10 Conclusions and Implications

The process of identifying integrated STEM curriculum implementation components, like that of the engineering design process, was an ongoing process of express, test, and redesign, which provided the research team with a continuous formative assessment of implementation fidelity. Working with the teacher participants to identify essential implementation components supported overarching program outcomes and mediate three main programmatic barriers to implementation (i.e., time, technology, and communication). The *interactional* implementation components identified in this study (i.e., *student mentorship*, *problem identification*, *culturally relevant pedagogy*, *team roles and responsibilities*, *reflection*, and *supportive technology*) are innovative to MEAs and illustrative to mediating programmatic barriers to implementation.

This study illustrates a model that leads to teacher success when implementing an innovative integrated STEM curriculum. Key implications of the implementation model are a framework that supports collaborative efforts between teachers and researchers to leverage the respective strengths of data collection, data analysis, and overachieving project outcomes where innovative integrated STEM curriculum is concerned. Furthermore, the *interactional* implementation components identified in this study (i.e., *student mentorship*, *problem identification*, *culturally relevant pedagogy*, *team roles and responsibilities*, *reflection*, and *supportive technology*) also reflect an innovative approach to implementing an integrated STEM curriculum.

3.11 Recommendations for Future Research

Future research may examine the influence of school and classroom contextual learning, including teacher expertise and student engagement on AgS MEA implementation. Exploring these factors may provide valuable information about system-level conditions to facilitate positive student outcomes using an innovative integrated STEM curriculum (i.e., AgS MEAs). Additionally, future research is critical to investigating the influence of various implementation components on student outcomes such as STEM attraction, STEM retention, and STEM diversity, especially at the elementary school level. Research of this nature is necessary because studies show that many students have settled into a career direction by elementary school that becomes more difficult to change as they age (Auger, 2005).

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CHAPTER 4. ASSESSING STUDENTS' INTEREST AND MOTIVATION IN STEM THROUGH AGRICULTURAL SCIENCES FOCUSED MODEL ELICITING ACTIVITIES

A version of this chapter was submitted for publication in the Journal of Agricultural Education.

Clark, Q. M., & Esters, L. T. (in review). Assessing students' Interest and Motivation in STEM Through Agricultural Sciences Focused Model Eliciting Activities.

4.1 Abstract

This study profiles the work generated by a large, multi-year, nationally grant-funded project. The project's goals were to design, develop, and field-test novel integrated science, technology, engineering, and mathematics (STEM) learning experiences using AgS contexts. Seven AgS MEAs were designed, developed, and field-tested during three academic school years. This innovative curriculum aimed to: (a) increase the number of underrepresented elementary school students prepared for secondary STEM courses and postsecondary majors in STEM, and (b) contribute to culturally relevant integrated STEM curriculum. The AgS MEAs were standards-based, grounded in culturally relevant pedagogy principles, and contextualized through community connections and local STEM industry partnerships. This qualitative study examined urban elementary students' (N = 67) interest and motivation to learn AgS and STEM. Specifically, the researcher sought to determine a difference between fifth and sixth grader's interest and motivation after participating in AgS MEAs. The fifth-graders participated in two AgS MEAs, and the sixth-graders participated in four AgS MEAs. The study took place in a K-6 environmental magnet school located in a large urban school district. Self-determination theory was used to focus on the contextual conditions that facilitate or forestall students' natural self-motivation process to engage and learn. Overall, there was no difference in interest and motivation between fifth and sixth-graders after participating in the AgS MEAs. This study is one of few studies that have examined differences in urban elementary students' interest and motivation to learn AgS and participate in integrated STEM learning activities.

4.2 Introduction

The challenges of meeting sustainable clean water, food, medicine, urban infrastructure, and clean energy for over 9 billion people by 2050 will require an agriculturally literate society (Borrows et al., 2020; Kovar & Ball, 2013). By the end of K-12 education, students must be agriculturally literate to make informed everyday decisions that affect the quality of life (Burrows et al., 2020; Kovar & Ball, 2013; Powell et al., 2008). Agricultural literacy involves understanding agricultural sciences (AgS), integrated STEM, and problem-solving (Burrows et al., 2020; Knobloch et al., 2007; Kovar & Ball, 2013; Powell et al., 2008).

The National Assessment of Educational Progress (NAEP) test scores indicated that in 2019 only 34% of U.S. 8th graders were proficient in STEM-related subjects and mathematical problem-solving by the end of the 8th grade (The Nation's Report Card, 2019). While there is an urgency to develop agricultural literacy and mathematical problem-solving skills among urban elementary school students, there is an even greater urgency to understand what motivates students to engage in and learn agricultural literacy and problem-solving (Baker & Robinson 2017; Williams & Williams, 2011). Studies conducted on the effects of experiential learning have yielded positive motivational outcomes (Baker & Robinson, 2017; 2016). However, few studies examined urban elementary students' motivation to learn agricultural literacy and problem-solve (Baker & Robinson, 2017; Mueller et al., 2015; Thoron & Burleson, 2014). An abundance of agricultural literacy research involves survey methodology, primarily focused on understanding teacher and student agricultural conceptual knowledge (Hess & Trexler, 2011; Knobloch & Martin, 2000; Pense et al., 2005; Reidel et al., 2007). Although understanding agricultural knowledge content levels among teachers and students is an important task, equally important is understanding students' interests in and motivation to learn agriculture, especially in urban areas where agricultural literacy programs are scarce. A study conducted by Martin and Kitchel (2014) reported barriers to agricultural literacy experienced by minority students from urban areas, including lack of participatory opportunity in nationally known programs such as National Future Farmers of America (FFA). For example, a National FFA (2018) report stated that of the more than 700,000 members, only 4.2% are Black, and 56% of FFA chapter locations are in predominately White rural areas, with only 5% of chapters located in urban areas. When underrepresented minority students from urban areas do not have access to large nationally known agricultural leadership organizations such as FFA, a gap in interest and motivation to learn AgS may continue to exist

(Martin & Kitchel, 2014). A study conducted by Lawrence et al. (2013) found that of 32 urban and rural FFA chapters, 71% of the rural agriculture students were FFA members compared to 52% of urban agriculture students.

AgS presents a unique opportunity to engage urban elementary school students in agricultural literacy and problem-solving. AgS addresses societal challenges such as health and human diet, food security/insecurity, alternative energy, and equitable green space distribution and utilization (National Center for Agricultural Literacy [NCAL], 2013). Understanding the impact of AgS on quality of life within contexts germane to local community problems is especially important for students who reside in urban areas. Students attending urban elementary schools are less likely to access agricultural literacy programs (Baker & Robinson, 2017; Mueller et al., 2015; Thoron & Burleson, 2014). The lack of access to AgS subject matter further exacerbates much-needed interest in and motivation to learn agricultural-related content (Baker & Robinson, 2017; Mueller et al., 2015; Thoron & Burleson, 2014). Furthermore, the AgS is an area underexplored as a context to promote interest and motivation for underrepresented minority students in urban K-12 settings (Baker & Robinson, 2017; Mueller et al., 2015; Thoron & Burleson, 2014).

Interest and motivation are essential precursors to learning and are critical constructs to study (Baker & Robinson, 2017; 2016; Pintrich, 2003; Pintrich & Schunk, 2002). Researchers and educators focus on the development of educational reform efforts including new instructional interventions and innovative learning technological tools. Additionally, there is a gap in the literature on research that addresses students' interest in and motivation to learn from these reform efforts is not included in teaching and learning research (Baker & Robinson, 2017; 2016; Pintrich, 1999; Pintrich & Schunk, 2002; Pintrich, 2003).

This study examined urban elementary students’ interest and motivation to learn AgS through STEM learning activities to address the gap in the literature. Specifically, the researcher looked at student’s interest in and motivation to learn AgS and participate in STEM learning experiences.

4.3 Background

4.3.1 Model Eliciting Activities (MEAs)

MEAs are realistic, client-driven problems that are inherently interdisciplinary and require student teams to develop a mathematical model to solve a problem (Diefes-Dux et al., 2008; English, 2009; English, 2003; Hamilton et al., 2008; Lesh & Doerr, 2003). MEAs are ideal tools for helping students connect content across and within curricula while engaging in mathematizing real-world problems (Diefes-Dux et al., 2008; English, 2009; Hamilton et al., 2008; Lesh & Doerr, 2003). MEAs support a planned sequence to multidisciplinary, interdisciplinary, and transdisciplinary curriculum approaches to integrated STEM (Roehrig et al., 2012; Stohlmann, 2019; Stohlmann et al., 2013; Vasquez et al., 2013). Unlike many of the tasks that students experience through the general curriculum, MEAs are problems, not exercises, that require students to develop a mathematical model to solve a problem (Diefes-Dux et al., 2008; English, 2009; Hamilton et al., 2008; Lesh & Doerr, 2003). As described by Bostic et al. (2020 a), a *problem* is a task that requires critical thinking because: (a) the solution strategy is unclear to the individual, (b) the number of solutions is uncertain, and (c) may be solved in more than one way. *Exercises* are tasks meant to foster students' facility and speed with a known procedure.

Using data in real-world contexts, MEAs facilitate learning by developing students' conceptual understandings and sense-making. MEAs require students to mathematize (e.g., quantify) information in context to develop a mathematical model as a procedure/product (Diefes-Dux et al., 2008; Hamilton et al., 2008; Lesh & Doerr, 2003). MEAs are thought-revealing in that they provide student teams an opportunity to self-reflect and provide teachers a window into students' thinking during problem solution development. MEAs draw upon express-test-re-design's iterative engineering problem-solving design cycle to facilitate students' critical thinking and problem-solving skills.

Six principles guide the design of MEAs (Diefes-Dux et al., 2008; Hamilton et al., 2008; Lesh & Doerr, 2003). These design principles require that all MEAs include: (1) model construction – a math model of a procedure/product, (2) realistic context – an authentic STEM-related problem, (3) self-assessment – an opportunity for student teams to self-assess the usefulness of the model, (4) model documentation – a procedure/product description, (5) model shareable and reusable – shareable and reusable for similar purposes, and (6) a useful learning prototype – a globally generalizable or modifiable procedure/prototype. These principles, developed by mathematics education researchers for elementary school classrooms (Diefes-Dux et al., 2008; Hamilton et al., 2008; Lesh & Doerr, 2003) were adapted for first-year college engineering courses. These principles also held promise for the instruction of other math and science-rich contexts.

MEAs were promoted as a tool primarily limited to researchers and practitioners:

- Researchers used MEAs to investigate K-12 and first-year college students' learning and thinking (Hamilton et al., 2008; Lesh & Doerr, 2003).
- Educational practitioners used MEAs to assess students' working conceptual knowledge.
- Researchers and practitioners used MEAs to identify highly gifted and creative students (Chamberlin & Moon, 2005; Coxbill et al., 2013; Hamilton et al., 2008).
- Researchers and practitioners also used MEAs to help students develop problem scoping skills and solve mathematical model problems (English, 2009; 2003; Glancy et al., 2018; Hamilton et al., 2008).

There are several examples of MEAs used by researchers and practitioners discussed in the literature. For instance, Hamilton et al. (2008) discussed several notable examples. This study used an innovative curriculum, AgS MEAs, as a tool to examine student's interest in and motivation to learn AgS and integrated STEM content, connect students to local community issues, and as a tool for STEM career exploration.

4.3.2 Agricultural Sciences (AgS) Model Eliciting Activities (MEAs)

A total of seven AgS focused MEAs were developed and field-tested over three academic school years. The AgS MEAs were the first-ever developed AgS focused model eliciting activities (MEAs). This study focused on student's interest and motivation during their participation in two of the eight AgS MEAs. All eight AgS MEAs were designed, developed, and field-tested using an iterative, cyclical design approach. Each AgS MEA underwent an express-test-redesign engineering design process (Clark et al., in review). All AgS MEAs adhered to the models and modeling perspective and associative principles (Bostic et al., 2021; Lesh & Doerr, 2003) and aligned with both Common Core State Standards Initiative ([CCSSI]), 2010) and *Next Generation Science Standards* ([NGSS]), 2013). The AgS MEA topics addressed four major societal challenges: (1) health and human diet, (2) food security/insecurity, (3) alternative energy, and (4) equitable green space utilization. The AgS related societal challenges facilitated a myriad of solutions requiring students to reflect on their everyday lives to connect challenges and resources in students' local communities. The AgS topics also provided a vibrant venue of real-world contexts to engage students in problem-solving that reflected culturally relevant pedagogy. Content experts guided the AgS MEA curriculum to ensure that the curriculum was culturally relevant, connected to the community, aligned with state content standards, and was developmentally appropriate for elementary school students.

Alignment of AgS MEAs with Culturally Relevant Pedagogy

Culturally relevant pedagogy (CRP) "empowers students intellectually, socially, emotionally, and politically using cultural referents to impart knowledge, skills, and attitudes" (Ladson-Billing, 2009, p. 16-17). A CRP framework encompasses three tenets: *academic achievement*, *cultural competence*, and *sociopolitical consciousness* (Ladson-Billing, 2009). Furthermore, research indicates that CRP plays a vital role in facilitating URM students' success in mathematics and science in K–12 education (Lesh et al., 2000; Lesh & Harel, 2003; Lesh & Doerr, 2003). CRP was especially critical when developing student's awareness of and connection to STEM careers and local community problems. CRP was incorporated into the design, development, and implementation of the AgS MEAs through the researchers' three C's of CRP. The researchers define the three C's as culture, community, and career. AgS MEAs were the first MEAs to incorporate the three C's into MEA design, development, and implementation.

The three Cs approach to CRP was achieved throughout the AgS MEA classroom instruction by providing teacher development sessions before and after each AgS MEA. The teacher development sessions increased teachers' knowledge, skill, and confidence in facilitating culturally and community-relevant learning activities tied to real-world situations. Providing teachers with resources to partner with local community organizations, local colleges, and universities, and local STEM networks empowered teachers with the confidence to implement CRP in their classrooms.

4.4 Theoretical Framework

This study was guided by self-determination theory (SDT; Deci & Ryan, 2012; 1982; Niemiec & Ryan, 2009; Ryan & Deci, 2000;). In this study, SDT was used as a framework focusing on the contextual conditions that facilitate or forestall our natural self-motivation process to engage and learn. SDT postulates that contextual factors enhance versus undermine motivation, specifically, intrinsic motivation (Deci & Ryan, 2012; 1982; Niemiec & Ryan, 2009; Ryan & Deci, 2000). Intrinsic motivation can be defined as those behaviors that inherently provoke interest and enjoyment in the absence of external incentives (Deci & Ryan, 2010). For example, “when people are intrinsically motivated, they play, explore, and engage in activities for the inherent fun, challenge, and excitement of doing so” (Niemiec & Ryan, 2009, p. 134). According to de Charms (1972), intrinsic motivation behaviors have an internal perceived *locus of causality*, meaning intrinsic motivation behaviors originate from the self rather than external sources. Intrinsic motivation is conveyed with inherent curiosity and interest (Deci & Ryan, 1982); thus, it exemplifies self-governing actions. Niemiec and Ryan (2009), mentioned that “motivation is central to humans’ inherent tendencies to learn and to develop” (p. 135). Deci and Ryan (2010) regard the construct of intrinsic motivation as the single influencer of our inherent tendency to seek out challenges and innovation, to extend and exercise our capacities, and to explore and learn. Further, essential to cognitive and social development is intrinsic motivation, the inclination toward natural interest and exploration (Deci & Ryan, 2012; 1982; Niemiec & Ryan, 2009; Ryan & Deci, 2000).

Although intrinsic motivation is inherent from birth, research indicates that the maintenance and enhancement of intrinsic motivation require certain conditions, especially where learning is concerned (Deci & Ryan, 1982; Ryan & Deci, 2000). Ryan and Deci (2000) go on to say that intrinsic motivation can be “fairly readily disrupted by various nonsuppurative conditions” (p. 70). SDT identifies three basic psychological needs that support requirements to stimulate and maintain intrinsic motivation (Niemiec & Ryan, 2009; Ryan & Deci, 2000). The need for competence (Harter, 1978), relatedness (Baumeister & Leary, 1995; Reis, 1994), and autonomy (Deci & Ryan, 2010; deCharms, 1972) have been identified as required conditions for intrinsic motivation.

The need for autonomy refers to students having a choice and option of pedagogical practices in the classroom (e.g., students experience autonomy when given a choice of a particular collaborative or active learning practice). The need for competence refers to students’ content self-efficacy (e.g., students experience competence when they believe that classroom content can be mastered). The need for relatedness refers to the sense of belonging that students experience through culturally relevant pedagogy (e.g., culturally relevant pedagogy connects students to content, community, and classmates). When these three basic needs are not met, students can experience academic disengagement and adverse learning outcomes (Niemiec & Ryan, 2009). Conversely, when supported, the need for autonomy, competence, and relatedness are associated with motivation, academic engagement, and enhanced learning outcomes (Niemiec & Ryan, 2009).

4.5 Purpose and Objectives

This study examined urban elementary students' interest and motivation in agricultural sciences and STEM learning experiences after participating in AgS MEAs. The research questions that guided this study were:

1. How does the level of student interest and motivation in agricultural sciences compare among students who engaged in two MEAs versus students who engaged in four MEAs?
2. How does the level of student interest and motivation in STEM learning activities compare among students who engaged in two MEAs versus students who engaged in four MEAs?

4.6 Context of the Study

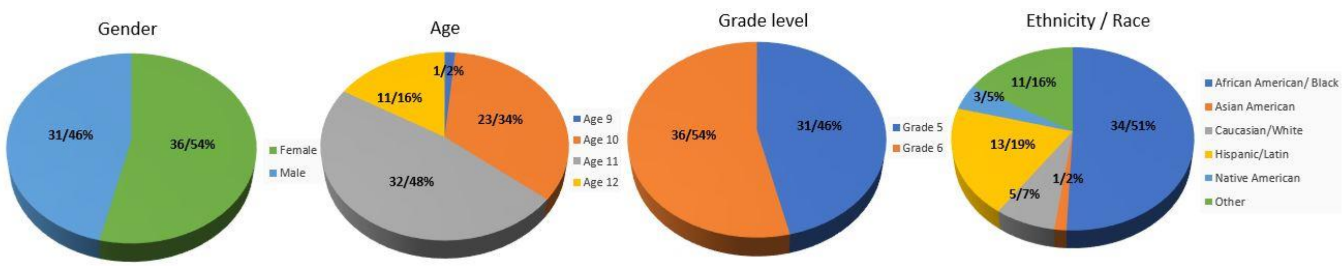
This study profiles the work generated by a large, multi-year nationally grant-funded project titled Modeling Agricultural Life Sciences Through STEM Integration. The project's goals were to design, develop, and field-test novel integrated STEM learning experiences using AgS contexts. Seven AgS MEAs were designed, developed, and field-tested during three academic school years. This innovative curriculum aimed to: (a) increase the number of URM elementary school students prepared for secondary STEM courses and postsecondary majors in STEM, and (b) contribute to culturally relevant integrated STEM curriculum. The AgS MEAs were standards-based, grounded in culturally relevant pedagogy principles, and contextualized through community connections and local STEM industry partnerships.

The study took place in the U.S. Midwest region at a K-6 environmental magnet school located in a large inner-city urban school district. The U.S. Department of Education defines a magnet school as offering a range of distinctive education programs emphasizing mathematics, science, technology, visual and performing arts, or humanities (U.S. Department of Education, 2004). In the context of this study, the magnet school focused primarily on STEM education. The school comprised an 83% minority population, including 85% Black, African American, 8% Hispanic, 6% Caucasian/White, and 1% Asian. Sixty-one percent of students receiving free or reduced lunch assistance. A goal of the school was to integrate environmental and AgS into an elementary education curriculum. To help achieve this mission, researchers associated with the project supported the school in preparing for and receiving STEM certification through the Indiana Department of Education (Indiana Department of Education, 2020).

4.6.1 Student Participants

Sixty-seven students participated in the study, including 31 fifth-graders (46.3%) and 36 sixth-graders (53.7%). Thirty-six (53.7%) of participants were female, and 31 (46.3%) were male. Approximately 50% of the students were African American/Black, almost 20% were Hispanic/Latinx, and the remaining distribution among Other/Biracial, and Caucasian/White. Sixteen (23.9%) of participants were in Mr. S's fifth-grade classroom, 15 (22.4%) were in Mrs. N's fifth-grade classroom, 17 (25.4%) were in Mrs. W's sixth-grade classroom, and 19 (28.4%) were in Mrs. M's sixth-grade classroom. The fifth-grade participants experienced two MEAs over one school year, and the sixth-grade participants experienced four MEAs over two school years.

Table 4.1 summarizes participants' demographic characteristics.



Note. Grades five and six represented four classrooms (i.e., two fifth-grade and two sixth-grade classrooms, N = 67).

4.6.2 Teacher Participants

Four elementary school teachers participated in this study for each of the two AgS MEA implementations during one academic school year. One week before each of the two AgS MEA implementations, teacher participants attended a 45-minute development session. Teacher participants received a stipend for participating in each development session. The goal of the development sessions was to: (a) conduct an explanatory demonstration of the AgS MEA; (b) engage teachers in a reflective discussion about AgS MEA implementation; and (c) engage teachers in conversations about students' motivation, culturally relevant pedagogy, community engagement, and STEM career exploration. Teacher participants received a stipend and instructional supplies for participating in the study. Two teachers taught fifth-grade, and two teachers taught sixth-grade. Teacher participants included one Caucasian, White male teacher and three Caucasian, White female teachers. Years of teaching experience ranged from two years to more than 15 years. The teacher's subject expertise area included English language arts (ELA), mathematics, and science. Table 4.2 summarizes teacher participants' demographic characteristics.

Table 4.1. Description of Teacher Participants

Teacher Name	Grade Level	Ethnicity/Race	Subject Expertise	Years of Teaching Experience
Christine	5	Caucasian/ White	English Language Arts	<10
Sam	5	Caucasian/ White	Mathematics	>5
Tina	6	Caucasian/ White	English Language Arts	<5
Montana	6	Caucasian/ White	Science	<15

Note. Pseudonyms are used to protect the anonymity of teacher participants.

4.7 Methods and Procedures

4.7.1 Instrumentation

The measures used in this study were modified from two previously established instruments, the Intrinsic Motivation Inventory (IMI, Deci & Ryan, 1982; Ryan et al., 1991; Ryan et al., 1991) and the Agricultural, Food, Natural Resources (AFNR) instrument (Knobloch et al., 2016; Scherer, 2016; Esters & Luster, 2004). The instruments were subjected to the Flesch-Kincaid readability test to ensure appropriate grade-level readability (Kincaid et al., 1975).

The purpose of the IMI was to assess students' subjective experiences related to a target activity. The IMI has been used in several studies and shown to produce adequate reliability and validity scores (Deci et al., 1994; Deci & Ryan, 1982; Ryan et al., 1991). The IMI included six scales. The lead researcher of this study adapted the following four subscales: (1) perceived confidence (PC); (2) effort/importance (EI); (3) value usefulness (VU); (4) and interest/enjoyment (IE) to measure interest in and motivation in participating in STEM learning activities. The resulting IMI questionnaire included 21 items (See Appendix C). Five items comprised three subscales (PC, EI, VU), and six items comprised one subscale (IE). Each of the 21 item response continuum is a 4-point Likert scale ranging from 1 = Not at all agree, 2 = Slightly agree, 3 = Somewhat agree, and 4 = Mostly agree, indicating the extent to which participants agreed or disagreed with each item of the scale. Cronbach's α coefficient of internal consistency scores was α = .87, α = .79, α = .87, and α = .71, respectively.

The purpose of the AFNR instrument was to assess youth interest and motivation to learn agricultural content. The instrument was used in several studies and produced adequate reliability and validity scores (Esters & Luster, 2004; Knobloch et al., 2016; Scherer, 2016). The instrument was modified for this study to measure interest and motivation in AgS. The instruments were subjected to the Flesch-Kincaid readability test to ensure appropriate grade-level readability (Kincaid et al., 1975). The resulting questionnaire included 21 items (See Appendix B). Each of the 21 items' response continuum is a 4-point Likert scale ranging from 1 = Strongly disagree, 2 = Disagree, 3 = Agree, and 4 = Strongly agree, indicating the extent to which participants agreed or disagreed with each item of the scale. Cronbach's α coefficient of internal consistency score was α = .89. From here onward, we refer to the modified AFNR instrument as the AgS questionnaire.

4.7.2 Data Collection and Analysis

Data were collected before and after the implementation of each of the two AgS MEAs. Before starting the first AgS MEA, demographic data were collected along with the AgS questionnaire data. One day after the completion of each of the two AgS MEAs, IMI data were collected. In total, one demographic questionnaire, one AgS questionnaire, and two IMI questionnaires were collected from each of the two fifth-grade and sixth-grade classrooms. Two graduate student researchers administered each questionnaire. While one graduate student researcher distributed the questionnaire to each student, the other graduate student researcher explained the questionnaire to the student participants question by question to ensure that students understood each question.

Data were analyzed using Statistical Package for Social Sciences (SPSS©) version 20. First, reliability coefficient scores were calculated for each of the five scales measuring interest and motivation. The five scales measuring interest and motivation were perceived confidence (PC), effort/importance (EI), value usefulness (VU), and interest/enjoyment (IE). Second, frequencies, percentages, means, and standard deviations were calculated for the AgS interest and motivation scale, and summated scores were calculated for the four IMI scales. Third, independent *t*-tests were conducted to assess differences in students' interest and motivation across all five scales between students who experienced two MEAs (fifth-graders) versus four MEAs (sixth-graders). The assumption of normality was examined for each *t*-test and met.

4.8 Findings

The first research question sought to determine interest and motivation between students who experienced two MEAs (fifth-graders) versus four MEAs (sixth-graders). Results of the independent *t*-test indicated no significant difference in mean scores for interest and motivation in AgS (fifth-grade mean = 2.75, SD = .59 and sixth-grade mean = 2.75, SD = .51; $t(65) = .037$, $p = > .05$. The AgS questionnaire scale revealed a trivial effect size (Cohen's $d = 0.0$) (see Table 4.3).

Table 4.2. Summated Scores and T-test Results for Grades 5 and 6

AgS Scale Means & Standard Deviations	*2 MEAs* *5th Grade* *n = 31*	*4 MEAs* *6th Grade* *n = 36*	*p = Value*	*Cohen's d*
AgS Interest & Motivation	M = 2.75, SD = .59	M = 2.75, SD = .51	.970	0.0

Note. M = mean, SD = standard deviation, and *n* = 67.

The second research question sought to determine student motivation in STEM learning experiences among students who experienced two MEAs (fifth-graders) versus four MEAs (sixth-graders). The summated means and standard deviations were calculated for participants' responses to items measuring perceived confidence (PC), effort/importance (EI), value usefulness (VU), and interest/enjoyment (IE). Table 4.4 displays the summated means and standard deviations along with the independent *t-tests* scores for each of the four constructs measured (i.e., PC, EI, VU, and IE).

Table 4.3. Summated Scores and T-test Results for Grades 5 and 6

Intrinsic Motivation Inventory Scale Means & Standard Deviations	*2 MEAs* *5th Grade* *n = 31*	*4 MEAs* *6th Grade* *n = 36*	*p-Value*	*Cohen's d*
Perceived Confidence (PC)	M = 3.19, SD = .76	M = 3.07, SD = .83	.548	0.12
Effort/Importance (EI)	M = 3.21, SD = .68	M = 2.97, SD = .74	.171	0.24
Value Usefulness (VU)	M = 2.79, SD = .81	M = 2.35, SD = .91	.042	0.44
Interest/Enjoyment (IE)	M = 2.99, SD = .89	M = 2.50, SD = .68	.014	0.49

Note. M = mean, SD = standard deviation, and $n = 67$.

Results of the independent *t*-tests indicated no significant difference in mean scores for Perceived Confidence (fifth-grade mean = 3.19, SD = .76 and sixth-grade mean = 3.07, SD = .83; $t(65) = -.605$, $p = > .05$). The Perceived Confidence scale revealed a trivial effect size (Cohen's $d = 0.12$). There was no significant difference in mean scores for Effort/Importance (fifth-grade mean = 3.21, SD = .68 and sixth-grade mean = 2.97, SD = .74; $t(65) = -1.37$, $p = > .05$). The Effort/Importance scale revealed a small effect size (Cohen's $d = 0.24$). However, there was a significant difference in mean scores for Value Usefulness (fifth-grade mean = 2.79, SD = .81 and sixth-grade mean = 2.35, SD = .91; $t(65) = -2.06$, $p = \leq .05$). The Value Usefulness scale revealed a moderate effect size (Cohen's $d = 0.44$). There was also a significant difference in mean scores for Interest/Enjoyment (fifth-grade mean = 2.99, SD = .89 and sixth-grade mean = 2.50, SD = .68; $t(65) = -2.57$, $p = \leq .05$). The Interest/Enjoyment scale revealed a moderate effect size (Cohen's $d = 0.49$).

4.9 Discussion

Participant's responses to the AgS interest and motivation questionnaire revealed no difference between the fifth-grade and sixth-grade students' interest and motivation levels. First, the AgS MEAs were designed and developed to meet the same CCSS grade level, facilitating a cognitive load appropriate for an urban classroom with varying student achievement levels. Second, teachers from the fifth- and sixth-grade classrooms experienced teacher development on implementing the AgS MEAs in the classrooms using the three C's: culture, community, and career. Third, the AgS MEAs were grounded in tenets of SDT (Deci & Ryan, 2012; 1982; Niemiec & Ryan, 2009; Ryan & Deci, 2000). Finally, the AgS MEAs were designed, developed, and implemented to support students' three basic psychological needs: competence, relatedness, and autonomy, supported through the three Cs.

Participant's responses to the IMI questionnaire indicated slight differences between the fifth-grade and sixth-grade students' interest and motivation levels. The fifth-graders composite scores for the four constructs measuring interest and motivation showed slightly higher interest and motivation in learning AgS and participating in integrated STEM learning activities. Recall that the fifth-graders experienced two AgS MEAs, and the sixth-graders experienced four AgS MEAs. The two additional AgS MEA topics that the sixth-graders experienced may have been rated by the sixth-graders as more favorable. This difference in interest and motivation could be based on students' advantage of experiencing four versus two AgS MEAs. Furthermore, the slight differences in interest and motivation can represent students' expressing competence, relatedness, and autonomy as described through SDT (Deci & Ryan, 2012; 1982; Niemiec & Ryan, 2009; Ryan & Deci, 2000).

While this study suggests that urban elementary students can benefit from integrated STEM learning experiences that use AgS contexts. SDT posits that while intrinsic motivation is inherent from birth, intrinsic motivation is multi-faceted, requiring ongoing maintenance of three basic psychological needs. The three basic psychological needs include the need for competence (Harter, 1978), relatedness (Baumeister & Leary, 1995; Reis, 1994), and autonomy (Deci & Ryan, 2010; deCharms, 1972). Students in this study may have found the AgS MEAs challenging, impacting students' ability to feel competence and relatedness.

4.10 Limitations

There is one limitation associated with this study. This study did not examine the complexities of having elementary school students engaging in MEAs. A qualitative examination of how complex it is for elementary students to engage in MEAs may have identified those factors that influenced students' interest and motivation to learn STEM and AgS. A qualitative study may identify contextual supports and barriers (i.e., parent influences, extracurricular activities, community connections, social media, friends, and mentorship that support self-determination). Furthermore, qualitative data often yields rich data that allows researchers to understand students' perceptions of a phenomenon better.

4.11 Implications

This study has implications for the urban elementary curriculum because it supports the need to understand what motivates students to engage in and learn agricultural literacy and problem-solving (Baker & Robinson 2017; Williams & Williams, 2011). This work also has implications for implementing culturally relevant pedagogy in urban elementary classrooms. CRP "empowers students intellectually, socially, emotionally, and politically using cultural referents to impart knowledge, skills, and attitudes" (Ladson-Billing, 2009, p. 16-17).

4.12 Recommendations for Future Research

The researcher recommends future research explore the following three areas: (1) factors influencing urban students' interest and motivation, (2) SDT tenets as core design components of curriculum design and development, and (3) AgS MEAs as a means to introduce students to agricultural sciences in urban elementary classrooms. First, to better understand factors influencing urban students' interest and motivation, a correlational study could examine relationships among contextual factors such as cultural referents, gender, age or educational levels, and interest and motivation levels. Contextual factors have been cited as essential in students' academic interest and motivation (Baker et al., 2012; Ladson-Billings, 2009). Seconds, future research might examine SDT as the core tenets of agricultural sciences education's curriculum design. Only a few studies examined urban elementary students' motivation or lack thereof to learn agricultural sciences and problem-solving (Baker & Robinson, 2017; Mueller et al., 2015; Thoron & Burleson, 2014). Lastly, future research could examine AgS MEAs as a means to introduce students to agricultural sciences in urban elementary classrooms. MEAs are known for helping students connect content across and within the curriculum and helping students learn to problem-solve (Diefes-Dux et al., 2008; English, 2009; Hamilton et al., 2008; Lesh & Doerr, 2003). MEAs are also known to support integrated STEM curriculum (Roehrig et al., 2012; Stohlmann, 2019; Stohlmann et al., 2013). AgS MEAs have been designed and developed to support integrated STEM curriculum, problem-solving, and culturally relevant pedagogy.

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CHAPTER 5. EPILOGUE

5.1 Conclusion

This three-study dissertation contributes to: (1) an innovative framework for an MEA design process and features, (2) an innovative model for MEA research and implementation, and (3) assessment data of students' interest in and motivation to learn integrated STEM and AgS, all of which culminated in the novel MEAs that facilitated contextual learning experiences that use AgS contexts. This work also provides insight into innovative teaching and learning instructional approaches that aligned with both Common Core State Standards ([CCSS], 2010) and Next Generation Science Standards ([NGSS], 2013). In particular, mathematical modeling, an emphasized topic in elementary grades' standards and curriculum is addressed. Mathematical modeling supports enhancing students' skills in critical thinking, problem-solving in real-world contexts, and improved application of mathematics. Using an engineering design process, I designed, developed, field-tested, and assessed seven AgS MEAs. Each of the AgS MEAs addresses a societal challenge (i.e., health and human diet, food security/insecurity, alternative energy, and green space utilization). The engineering design process enabled me to continually enhance and improve the design and implementation of the AgS MEAs through repeated testing, analyses, and re-design.

The use of AgS contexts in K-12 is essential. AgS contents are logically linked to just about all of the 14 Grand Challenges for Engineering in the 21st Century (National Academy of Engineers [NAE], 2021) for sustaining improved life on the planet. The challenges of meeting sustainable clean water, food, medicine, urban infrastructure, and clean energy needs for over nine billion people by 2050 will require a society that has working knowledge of AgS contexts (i.e., health and human diet, food security/insecurity, alternative energy, and green space utilization) (Borrows et al., 2020; Kovar & Ball, 2013). AgS are interdisciplinary areas that have been mainly underexplored as a learning context for K-6. AgS contexts provide a wide venue for real-world engineering-based rich problem-solving tasks culturally relevant to one's environment. Contextual learning experiences using AgS can be a powerful approach to engage students from urban areas in STEM career literary learning activities that connect to local community issues. Furthermore, because AgS consists of food, plants, and animals, students have the opportunity to make real-life connections to areas that are socially relevant to their everyday lives.

5.2 Summary of Major Findings

The first study describes a process for designing and developing AgS MEAs. Data sources for this qualitative study included iterative documentation and expert evaluations. The central finding of this study was a process for designing and developing AgS MEAs. The second study identified and characterized essential structural and interactional implementation components of the AgS MEAs. This qualitative study's data sources included semi-structured teacher interviews (individual and focus group), recorded teacher development sessions, and documented expert consultations. This study's findings suggest implementation components that support contextual teaching and learning, self-regulated learning, culturally relevant pedagogy, multiple contexts, authentic assessment, and interdependence. The third study assessed students' interest in and motivation to learn STEM and AgS. Data sources included the intrinsic motivation inventory and the agricultural, food, natural resources scales. This study's findings suggest that AgS MEAs may positively promote interest in and motivation to learn AgS, STEM, and STEM career exploration

5.3 Limitations

There are two limitations associated with study one. The first limitation is an academic expert's perspective on equitable teaching and learning was brought into the design process later than desired. However, the academic associated with the design and development of the AgS MEAs was an expert in culturally relevant pedagogy and literacy practices; however, they did not have a background in equitable STEM education teaching and learning practices. Equitable teaching and learning practices are important within mathematics instruction (National Council of Teachers of Mathematics, 2014). Equitable mathematics teaching practices provide all students with opportunities to use multiple ways of engaging in classroom discourse. The second limitation is that this study was a case study. A case study can generate an in-depth understanding of a complex issue in its real-life context; however, a case study can also limit the context to understand.

There are three limitations associated with study two. First, the number of teacher participants and classrooms may have been a limiting factor. Although this study focused on seven teachers and four classrooms, which may be considered low, it is important to revisit the qualitative methodological approach's value and purpose. Despite the ongoing debate about credibility, case study research is an increasingly popular and purposeful approach to conducting qualitative research (Hyett et al., 2014). The qualitative approach to the case study was designed to suit the case (five MEA implementations across seven classroom teachers) and our research questions. Emphasis was placed on full implementations across multiple classrooms over several years. Therefore, these implementations constitute a viable sample size. Additional teacher participants and classrooms could strengthen the study design. The second limitation is that this study did not include other data generated in the overall grant project. The AgS MEA implementations produced data that included student artifacts (e.g., final student presentations of the AgS MEA solutions and the AgS MEA workbooks). Analysis of these student artifacts could provide insight into student engagement with each identified essential implementation component. Lastly, the third limitation is the variability across the teacher classrooms. Based on the work generated from the larger grant project, it was clear that each classroom experienced different instructional and school-based challenges, including low student engagement and disruptive student behavior. As we continued working with the teacher participants, it was clear that the feedback they provided the structures they needed to implement the AgS MEAs successfully.

Additionally, the teachers' feedback was a testament to the need for these components for MEA implementation and applying the engineering design process as a systematic method to gather and utilize iterative and constructive teacher feedback. A classroom's context can be a valuable lens for understanding how implementation components may influence classroom complexities that may affect teaching and learning. Analyzing how specific implementation components may influence classroom complexities could provide viable insights into enacting pedagogical practices that promote equitable outcomes for students and teachers.

There is one limitation associated with study three. This study did not examine open-ended questions through structured and unstructured interviews, focus groups, or observations. An examination of open-ended questions may have revealed qualitatively those factors that influenced students' interest and motivation to learn STEM and AgS. A qualitative study that examined those contextual supports and barriers (i.e., parent influences, extracurricular activities, community connections, social media, friends, mentorship) may capture emerging data that can help researchers better understand how students perceive and make sense of contextual supports and barriers. Furthermore, non-numerical data often yields rich data that allows researchers to understand students' perceptions of a phenomenon better.

5.4 Key Implications for Practice

The Consortium for Mathematics and Applications (COMAP, Campbell, 2007) and the Annual Perspectives in Mathematics Education (Hirsch & McDuffie, 2016), along with many other published materials about MEAs, provide several examples of MEAs and information about their implementation. Yet, such scholarship stops short of providing a roadmap, process, or framework for others interested in developing didactic MEAs.

Study one fills a gap in the MEA literature on MEA design and development by providing design processes and features to guide future MEA design and development. A key implication of the design process and features is a framework and roadmap for researchers and teachers to design and develop MEAs.

Study two fills a gap in the MEA literature on implementing an innovative integrated STEM curriculum, Ag MEAs, by providing a model for implementing AgS MEAs and an example of how teachers can monitor and analyze the fidelity of implementing an innovative STEM curriculum. Key implications of the implementation model are a framework that supports collaborative efforts between teachers and researchers to leverage the respective strengths of data collection, data analysis, and overachieving project outcomes where innovative integrated STEM curriculum is concerned. Furthermore, the *interactional* implementation components identified in this study (i.e., student mentorship, problem identification, culturally relevant pedagogy, team roles and responsibilities, reflection, and supportive technology) are innovative to MEAs and illustrative to mediating programmatic implementation barriers.

Study three fills a gap in MEA literature on assessing students' interest in and motivation to learn integrated STEM by evaluating students' interest in and motivation to learn integrated STEM. This study has implications for the urban elementary curriculum because it supports the urgency to understand what motivates students to engage in and learn agricultural literacy and problem-solving (Baker & Robinson 2017; Williams & Williams, 2011). This work has implications for implementing culturally relevant pedagogy in urban elementary classrooms. CRP "empowers students intellectually, socially, emotionally, and politically using cultural referents to impart knowledge, skills, and attitudes" (Ladson-Billing, 2009, p. 16-17).

5.5 Further Research

MEAs are known for helping students connect content across and within the curriculum while helping students learn to problem-solve in real-world contexts (Diefes-Dux et al., 2008; English, 2009; Hamilton et al., 2008; Lesh & Doerr, 2003; Roehrig et al., 2012; Stohlmann, 2019; Stohlmann et al., 2013). However, little to no scholarship explores the use of MEAs to connect elementary students to AgS content (i.e., health and human diet, food security/insecurity, alternative energy, and green space utilization). In addition, no known scholarship explores MEAs and culturally relevant pedagogical practices to support the exploration of STEM careers through local STEM industry and community issues. This body of work fills these gaps in research and literature.

What does the future hold for the pedagogical practice of AgS MEAs? More specifically, how might this work be different if I conduct this research a decade from now? One answer is that I would research AgS MEAs implemented via a virtual reality (VR) lab using computer-aided modeling instead of classroom implementation. For example, an activity that involves planting and growing food products requires time for outdoor planting, cultivating, and harvesting. A computerized version of the MEA can deliver near-instantaneous feedback, allowing students to explore and learn while their attention is focused on the lesson more quickly.

Second, most real-world STEM activities involve advanced concepts from science and mathematics that can be difficult for elementary school students to grasp at first. To address this problem, I would investigate having students control the bounded parameters of a model while noticing the result. Controlling the parameters of an experiment is what professional scientists do when they develop models of new phenomena. I want students to do a similar exploratory activity or role-play in a VR lab environment by tweaking the model's parameters and observing the results. Finally, the students would create their model to predict the more realistic and complex tool's model.

Advancing AgS MEAs through VR labs, where computer-aided modeling is used for students role-play as STEM professionals to solve a practical STEM problem can enable deeper experiential learning for students with rich contextual experiences. Student teams will engage in VR learning activities as they engage in role-play activities as STEM professionals. Student engagement can occur both synchronous and synchronous. Assessment can occur through learning analytics. Through VR, they enhance AgS, plus the three Cs (culture, community, and career) experience has yet to be investigated. My overarching research goals would be to facilitate students' understanding of how STEM works, the importance of AgS, and the facilitation of AgS, STEM, and the real-world connections, thereby enhancing learning self-efficacy.

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Williams, K. C., & Williams, C. C. (2011). Five key ingredients for improving student motivation. *Research in Higher Education Journal*, *12*, 1. http://aabri.com/manuscripts/11834.pdf

APPENDIX A. IRB APPROVAL

PURDUE
UNIVERSITY

HUMAN RESEARCH PROTECTION PROGRAM
INSTITUTIONAL REVIEW BOARDS

To:	LEVON ESTERS AGAD
From:	JEANNIE DICLEMENTI, Chair Social Science IRB
Date:	09/25/2017
Committee Action:	**Expedited Approval of Amendment**(6) (7)
IRB Approval Date	09/25/2017
IRB Protocol #	1505016094
Funding Source:	**NATIONAL SCIENCE FOUNDATION: Grant # 1513256**
Study Title	Strategies Project: Enhancing Minority Middle School Student Knowledge, Literacy and Motivation in STEM Using Contextualized Agricultural Life Science Learning Experiences
Expiration Date	05/09/2018
Subjects Approved:	990

The above-referenced protocol has been approved by the Purdue IRB. This approval permits the recruitment of subjects up to the number indicated on the application and the conduct of the research as it is approved.

The IRB approved and dated consent, assent, and information form(s) for this protocol are in the Attachments section of this protocol in CoeusLite. Subjects who sign a consent form must be given a signed copy to take home with them. Information forms should not be signed.

Record Keeping: The PI is responsible for keeping all regulated documents, including IRB correspondence such as this letter, approved study documents, and signed consent forms for at least three (3) years following protocol closure for audit purposes. Documents regulated by HIPAA, such as Authorizations, must be maintained for six (6) years. If the PI leaves Purdue during this time, a copy of the regulatory file must be left with a designated records custodian, and the identity of this custodian must be communicated to the IRB.

Change of Institutions: If the PI leaves Purdue, the study must be closed or the PI must be replaced on the study through the Amendment process. If the PI wants to transfer the study to another institution, please contact the IRB to make arrangements for the transfer.

Changes to the approved protocol: A change to any aspect of this protocol must be approved by the IRB before it is implemented, except when necessary to eliminate apparent immediate hazards to the subject. In such situations, the IRB should be notified immediately. To request a change, submit an Amendment to the IRB through CoeusLite.

Continuing Review/Study Closure: No human subject research may be conducted without IRB approval. IRB approval for this study expires on the expiration date set out above. The study must be close or re-reviewed (aka continuing review) and approved by the IRB before the expiration date passes. Both Continuing Review and Closure may be requested through CoeusLite.

Unanticipated Problems/Adverse Events: Unanticipated problems involving risks to subjects or others, serious adverse events, and serious noncompliance with the approved protocol must be reported to the IRB immediately through CoeusLite. All other adverse events and minor protocol deviations should be reported at the time of Continuing Review.

Ernest C. Young Hall, 10th Floor - 155 S. Grant St. - West Lafayette, IN 47907-2114 - (765) 494-5942 - Fax: (765) 494-9911

APPENDIX B. AGRICULTURAL, FOOD, NATURAL RESOURCES INTEREST SCALE

Directions: Please indicate the degree to which you agree or disagree with the statements below by circling the appropriate number to the right of each statement.

Student ID Number________________	Strongly Disagree	Disagree	Agree	Strongly Agree
1. I am interested in learning about how living things grow and develop.	1	2	3	4
2. I am interested in visiting a greenhouse.	1	2	3	4
3. I am interested in observing wildlife in a zoo.	1	2	3	4
4. I am interested in learning about a dairy farm.	1	2	3	4
5. I am interested in visiting a food-manufacturing plant.	1	2	3	4
6. I am interested in learning about farm animals.	1	2	3	4
7. I am interested in going on a field trip to visit a grain farm.	1	2	3	4
8. I am interested in visiting a science lab.	1	2	3	4
9. I am interested in learning about plant genes.	1	2	3	4
10. I am interested in participating in a river cleanup.	1	2	3	4
11. I am interested in learning about how to plant seeds.	1	2	3	4
12. I am interested in gardening.	1	2	3	4
13. I am interested in going on a field trip to an orchard.	1	2	3	4
14. I am interested in learning about agricultural machinery, like a tractor.	1	2	3	4
15. I am interested in observing a butterfly in the garden.	1	2	3	4
16. I am interested in solving environmental problems (i.e., climate change and pollution).	1	2	3	4
17. I am interested in going camping in a forest.	1	2	3	4
18. I want to be involved in research to help develop improved plants and food crops.	1	2	3	4
19. I am interested in learning how to sell agricultural products.	1	2	3	4
20. I am interested in designing packages for food.	1	2	3	4
21. I am interested in robots, drones, or other computer-controlled machines.	1	2	3	4

APPENDIX C. INTRINSIC MOTIVATION INVENTORY SCALE

Directions: Please indicate your personal opinion about each statement by circling the appropriate response to the right of each statement.

Student ID Number____________________ To what extent do you agree with the following statements regarding your learning experiences….		Not at all Agree	Slightly Agree	Somewhat Agree	Mostly Agree
1	I think I did pretty well on this activity compared to other students.	1	2	3	4
2	I tried very hard on this STEM (MEA) activity.	1	2	3	4
3	I would be willing to do this STEM (MEA) activity again because it has some value to me.	1	2	3	4
4	I put a lot of effort into completing this STEM (MEA) activity.	1	2	3	4
5	I believe doing this STEM (MEA) activity could be beneficial to me.	1	2	3	4
6	While doing this STEM (MEA) activity, I thought about how much I enjoyed it.	1	2	3	4
7	I am satisfied with my performance on the STEM (MEA) activity.	1	2	3	4
8	I think that doing this STEM (MEA) activity is helpful for my future career.	1	2	3	4
9	This STEM (MEA) activity was fun to do.	1	2	3	4
10	After working on this STEM (MEA) activity for a while, I felt pretty competent.	1	2	3	4
11	Doing this STEM (MEA) activity could help me pursue a career in science, technology, engineering, math (STEM).	1	2	3	4
12	I enjoyed doing this STEM (MEA) activity very much.	1	2	3	4
13	I would describe this STEM (MEA) activity as very interesting.	1	2	3	4
14	I believe the STEM (MEA) activity could be of some value to me.	1	2	3	4
15	It was important to me to do well on the STEM (MEA) activity.	1	2	3	4
16	I think the STEM (MEA) activity is important.	1	2	3	4
17	I thought the STEM (MEA) activity was boring.	1	2	3	4
18	I thought this STEM (MEA) activity was quite enjoyable.	1	2	3	4
19	I was skilled at this STEM (MEA) activity.	1	2	3	4
20	This STEM (MEA) activity is important because it can help me be successful in Science, Technology, Engineering, Math (STEM).	1	2	3	4
21	I think I was pretty good at this STEM (MEA) activity.	1	2	3	4

APPENDIX D. DEMOGRAPHIC SURVEY

Student ID Number: _________________

1. Age: ____________________

2. Grade: __________________

3. Gender: a. Male__________________ b. Female___________________

4. Teacher: ___________________

5. School: _____________________

6. Ethnicity/Race
   a. Caucasian/White
   b. African American/Black
   c. Native American/American Indian
   d. Asian/ Pacific Islander
   e. Hispanic
   f. Biracial
   g. Other: __________________

APPENDIX E. HEALTHY FOOD CHOICES 1.0

Healthy Foods Choices 1.0

Cover Page

Topic
Public health in the context of nutrition, related to food choices

Key Question
How do consumers use the Nutrition Facts Label information to make healthy food choices?

Goals
Students will:
1. Solve real-world problems using mathematical models
2. Cycle through the iterative engineering design cycle of express-test-revise
3. Engage in statistical thinking while working collaboratively
4. Make decisions about the effectiveness of a solution
5. Prepare written and verbal reports of a viable solution

Guiding Documents
This task has the potential to address some Standards for Mathematical Practices (SMPs) and Standard of Mathematics Content (SMC). However, as implementation strategies and student solutions may vary, not all standards may apply. Please see the list of Common Core State Standards (CCSS) that may apply.

Recommended Supplies for all Modeling-Eliciting Activities
It is recommended to have all supplies in a central location in the room. In addition, it is recommended to let the students know that they are available, but not to encourage them to use specific supplies.

- TI-15 Explorer Elementary or equivalent calculators
- Standard 12-inch rulers (metric or standard units)
- Colored pencils
- Number 2 pencils
- Wide ruled composition notebooks or loose-leaf paper

Advanced Organizer / News Article

Kids are learning to read the **Nutrition Facts Label** on food and drink containers to make smart food choices. A fun hip-hop song called *Dishin the Nutrition* talks about how easy it is to learn the nutrition facts that the food label provides. A part of the song goes like this, "Before you eat your food or satisfy your thirst – You gotta *Spot the Block* and get your food facts first." The Nutrition Facts Label is shaped like a block and located on most food containers anddrinks. Just like the song says, "it doesn't matter if it's in a bag, can, or box, the info is inside the block." The information that is inside the block is the total vitamins, minerals, protein, calories, etc., per container.

The nutrition facts that are listed on the food and drink containers may seem hard to read. The label has tiny printed words and is not always easy to understand. However, it contains important information about the food you eat. **Calories** are the amount of energy a food contains. **Fat, carbs, and protein** are substances that help our bodies to grow. **Fat** provides our body with energy from foods like nuts and fish. **Carbs** provide our body with the main sourceof energy from foods like pasta and fruit. **Protein** helps make muscle strong and can be found in foods like chicken and beans. **Vitamins** are the substances that are found in many foods that help our bodies develop and function. **Minerals** are natural chemicals like iron and calcium. Minerals are found in soil. There are other words in the label that may seem hard to understand at first sight, but like the song says, "You don't need permission, or supervision, for healthy living – just *Spot the Block*."

The body needs the right combination of the four parts of the Nutrition Facts Label to function and grow properly. Fat, carbs, protein, and vitamins are measured in **grams**, **milligrams**, and **micrograms.** Vitamins can be measured in milligrams and micrograms. A **gram** is also written in **g** and weighs about as much as a paper clip. A **milligram** is also written in **mg** and weighs as much as one single human hair. A **microgram** is also written in **mcg** and weighs as much as one grain of sand. The Nutrition Facts Label alsolists how many servings are in one container, which is called the serving size. It also contains the number of **calories** per serving.

THE 5 PARTS OF THE LABEL ARE LISTED BELOW

Part 1: Tells you the serving size
Part 2: List the number of calories in one serving
Part 3: List the amount of fat, carbs, and protein, etc.
Part 4: List the amount of vitamins and minerals like iron in each serving

FOOD FOR THOUGHT

Look for Nutrition Facts Labels on your favorite snacks. Once you *Spot the Block*, you will find all the nutrition information you need for making smart food serving sizes, then choose foods that are low in added sugar, fat, and sodium. Remember to share what you have learned about reading Nutrition Facts Labels with your family and friends. Remember to share what you have learned about reading Nutrition Facts Labels with your family and friends.

Mathematics: Read the Agriculture Life Science article, ***Get the Food Facts First*** and answer the questionsbelow. Use the Nutrition Facts Label on this page to answer the following six questions.

1. How many servings are there per container?
2. How many calories are there per serving?
3. How many calories are in the entire container?
4. How many grams of total sugar is in the entire container?
5. What % of Daily Value is the sodium for two servings?
6. If a person eats three servings of this food...
   a. How many calories have they eaten?
   b. What is the % Daily Value of total fat?
   c. What is the % Daily Value of sodium?
   d. What is the % Daily Value of added sugar?

Nutrition Facts

8 servings per container

Serving size **2/3 cup (55g)**

Amount per serving	
Calories	**230**
	% Daily Value*
Total Fat 8g	**10%**
Saturated Fat 1g	**5%**
Trans Fat 0g	
Cholesterol 0mg	**0%**
Sodium 160mg	**7%**
Total Carbohydrate 37g	**13%**
Dietary Fiber 4g	**14%**
Total Sugars 12g	
Includes 10g Added Sugars	**20%**
Protein 3g	
Vitamin D 2mcg	10%
Calcium 260mg	20%
Iron 8mg	45%
Potassium 235mg	6%

* The % Daily Value (DV) tells you how much a nutrient in a serving of food contributes to a daily diet. 2,000 calories a day is used for general nutrition advice.

<u>Key for Units of Measure</u>

cal = calories

ser = servings

g = grams

Readiness Questions II / Discussion Topics

Read the ***nutrition facts terms*** and ***match them to the definitions***. Write the correct letter of the definition next to the term. Use ***Ag Life Sciences News*** to assist you.

Definitions

A. A metric unit of mass that is about as much as a paperclip

B. A metric unit of mass that is about as much as a singlehuman hair

C. The block on foods that list nutrition facts

D. The amount of energy a food contains

E. The substances in food that help bodies to grow

F. Natural chemicals found in soil

G. The substances found in many foods which helpour bodies develop and function

H. A metric unit of mass that is about as much as a grain of sand

Nutrition Facts Terms	
Gram (g)	
Calories	
Milligram (mg)	
Minerals	
Nutrients	
Nutrition Fact Label	
Vitamins Microgram (mcg)	

Healthy Food Choices 1.0

Problem Statement

MEMORANDUM

To: The 5th Grade Students of Cold Spring Elementary
From: Karen Robinson, Director of Nutrition Education at Foods 'R' Us
Subject: Creating Healthy Eating Habits

I help people eat healthy by using the information on the Nutrition Facts Label. I help them figure out the right amount of fat, carbs, and protein they should eat each day. The amount of fat, carbs, and protein a person should eat each day depends on a person's age, sex, and level of physical activity. Many people do not know the right amount of fat, carbs, and protein they should eat each day.

Foods 'R' Us is developing a food app to help people make healthy food choices. The food app will help people figureout the right amount of fat, carbs, and protein to eat each day.

We need your help to develop a procedure that figures out the number of grams of fat, carbs, and protein a personshould eat each day. The data tables attached to this letter will help your team develop a procedure.

In a letter to Foods 'R' Us, describe how your procedure figures out the number of grams of fat, carbs, and protein a person should eat each day. Describe what person your team picked. Explain what the person might eat for breakfast, lunch, dinner, and snacks in a single day. Explain the number of grams of fat, carbs, and protein. Please explain how youtest your procedure to make sure it will work for all body types and ages. Foods 'R' Us will use a similar procedure for all people.

You may use math symbols, graphs, tables, words, equations, and pictures to explain your ideas. Take notes of your model development progress along the way because different ideas (right or wrong) are valuable. They remind us ofwhat works and what does not work.

You may also use the following steps to help develop your procedure.

Step 1. Use Tables 1a and 1b to pick a male or female. Pick an age group. Pick the level of activity.

Step 2. Use Tables 2a and 2b to decide what the person might eat and how many grams of fat, carbs, and protein are in each meal.

Step 3. Use Table 3 as a guide to help you pick healthy food choices for breakfast, lunch, dinner, and snacks. Then develop your procedure that figures out the number of grams of fat, carbs, and protein a personshould eat each day.

I look forward to hearing from you soon!

Sincerely,

Karen Robinson
Director of Foods 'R' Us

Healthy Food Choices 1.0

Levels of Physical Activity Data Set

The number of calories you need each day depends on the following three facts.

1. Your age
2. Your gender (male or female)
3. How active you are

The table below defines each level of activity.

Not Active	Somewhat Active	Very Active
Not much ENERGY used. Does only light activity. For example, cooking or walkingto the mailbox, cleaning the house, or playing video games, does only light activity that is needed for daily life.	Some ENERGY used. Does some physical activity. For example, walking fast for 1½ to 3 miles (about 30–40 minutes) each day, as well as light activity needed for daily life.	A lot of ENERGY used. Does physical activity. For example, walking fast for more than 3 miles each day (more than 40 minutes), running, playing soccer, or playing basketball, as well as light activity needed for daily life.

The number of calories needed differs by age, gender, and the level of regular physical activity.

- For children, more calories are needed at older ages.
- For adults, fewer calories are needed at older ages.

Table 1a

Calories Needed Each Day for Girls and Women

Age	Not Active	Somewhat Active	Very Active
2-3 years	1,000	1,000-1,2000	1,000-1,400
4-8 years	1,200-1,400	1,400-1,600	1,400-1,800
9-13 years	1,400-1,600	1,600-2,000	1,800-2,200
14 years and older	1,600-2,000	1,800-2,200	2,000-2,400

Table 1b

Calories Needed Each Day for Boys and Men

Age	Not Active	Somewhat Active	Very Active
2-3 years	1,000-1,200	1,000-1,4000	1,000-1,400
4-8 years	1,200-1,400	1,400-1,600	1,600-2,000
9-13 years	1,600-2,000	2,400-2,200	2,000-2,600
14 years and older	2,000-2,600	2,200-2,800	2,400-3,200

Healthy Food Choices 1.0

Food Nutrition Facts Data Set

Table 2a

FRUIT	CALORIES	FATS(g)	CARBS(g)	PROTEIN(g)
Apple, 1 med	80	0	22	0
Avocado, ½ med	50	4.5	3	1
Banana, 1 med	110	0	30	1
Blueberries, 1 c	83	0.5	21.0	1.1
Cantaloupe, ¼ med	50	0	12	1
Grapefruit, ¼ med	60	0	15	1
Grapes, ¾ c	90	0	23	0
Kiwifruit, 2 med	90	1	20	1
Lemon, 1 med	15	0	5	0
Lime, 1 med	20	0	7	0
Nectarine, 1 med	60	0.5	15	1
Orange, 1 med	80	0	19	1
Papaya, 1 c	55	0.2	11.2	0.9
Peach, 1 med	60	0.5	15	1
Pineapple, 2 slices	50	0	13	9
Plums, 1 med	37.5	0	9.5	0.5
Strawberries, 8 med	50	0	11	1
Cherries, 21 cherries	100	0	26	9
Tangerine, 1 med	50	0	13	1
Watermelon, 2 cs	80	0	21	1
VEGETABLES	**CALORIES**	**FATS(g)**	**CARBS(g)**	**PROTEIN(g)**
Asparagus, 5 spears	20	0	4	2
Beets, ½ c	29	0	6.5	1
Broccoli, 1 c	45	0.5	8	4
Brussels sprouts, 1 c	38	0	8	3
Carrots, 1 c	30	0	7	1
Cauliflower, 1 c	20	0.2	3.9	1.9
Celery, 1 c	42	0.3	9.1	1.5
Cucumber	16	0	2	0.5
Green (snap) beans, 1 c	131	0	7	2
Green Cabbage, ½ c	25	0	5	1
Iceberg Lettuce, ½ c	20	0	4	2
Kale, 1 c	8	0.1	1.4	0.7
Onion, 1 c	40	0	10	1
Pepper (bell), 1 med	25	0	6	1
Potato (white) 1 med	128	0.2	29	3.5
Potato (sweet) 1 med	115	0.2	27	2.1
Spinach, 1 c	41	0.5	6.8	5.3
Squash (summer), 1 c	74	5.4	6.1	2.6
Tomato, 1 med	22	0.3	4.8	1.1
Zucchini, med	33	0.6	6	4.9

Healthy Food Choices 1.0

Food Nutrition Facts Data Set

Table 2b

BEANS & GRAINS	CALORIES	FATS(g)	CARBS(g)	PROTEIN(g)
Beans (black), 1 c	227	0.9	41	15
Beans (chickpeas), 1 c	269	4.2	45	15
Beans (lentils), 1 c	226	0.8	39	18
Bread (wheat), 2 slices	154	1.9	28	6.2
Bread (white), 2 slices	198	2.4	36	6.6
Crackers (wheat), 4	38.4	1.4	6	0.6
Crackers (white), 4	80	4.4	10	1.1
Cookies, 2 med	296	14.8	40	3
Corn, 1 ear	99	1.5	22	3.5
Cornbread, 1 piece	173	4.6	28	4.4
Noodles (rice), 1 c	190	0.3	42	3.2
Noodles (spaghetti), 1 c	196	1.2	38	7.2
Oatmeal, 1 c	166	3.6	28	5.9
Popcorn (plain), 3 cs	90	1	19	3
Popcorn (buttered), 3cs	234	15.81	21.81	2.88
Pretzels, ½ c	436	3.3	92	11.2
Rice (brown), ½ c	109	0.8	23	2.3
Rice (white), ½ c	102.5	0.2	22.5	2.1
Tortilla (flour), 1 med	234	5.1	40	6.3
Waffle, 1	218	11	25	5.9
MEAT & FISH	**CALORIES**	**FATS(g)**	**CARBS(g)**	**PROTEIN(g)**
Chicken, 4 oz	249	14.7	0	26.7
Hamburger, 4 oz	262	16	0	28
Steak, 4 oz	230	22	0	19
Pork chop, 4 oz	289	17	0	29
Turkey , 4 oz	214	8.4	0	32
Fish, 4 oz	109	2.3	0	22
Salmon, 4 oz	234	14	0	25
Tuna, 4 oz	148	0.7	0	33
NUTS & SEEDS	**CALORIES**	**FATS(g)**	**CRABS(g)**	**PROTEIN(g)**
Almonds, 23	163	14	6	6
Peanuts, 23	161	14	4.6	7
Pumpkin seeds, 23	126	5	15	5
Sunflower seeds, 23	166	15	6	6
Walnuts, 14	185	18	3.9	4.3
DAIRY/NON-DAIRY	**CALORIES**	**FATS(g)**	**CRABS(g)**	**PROTEIN(g)**
Cheese, 1 slice	113	9.3	0.9	6.4
Egg, 1 whole	50	4.8	0.4	6.3
Ice cream, 1 c	273	15	31	4.6
Milk (almond), 1 c	56	2.5	8.1	1.1
Milk (whole), 1 c	125	4.7	12	8.5
Milk (soy), 1 c	100	4	8	7
Yogurt, 3 oz	53	1.3	6	4.5

Healthy Food Choices 1.0

Common Core State Standards Potential Addressed

CCSS.MATH.CONTENT.5.OA.A.2
Write simple expressions that record calculations with numbers and interpret numerical expressions without evaluating them. *For example, express the calculation "add 8 and 7, then multiply by 2" as 2 × (8 + 7). Recognize that3 × (18932 + 921) is three times as large as 18932 + 921, without having to calculate the indicated sum or product.*
Number and Operations in Base TenUnderstand the place value system.
Perform operations with multi-digit whole numbers and with decimals to hundredths.
CCSS.MATH.CONTENT.5.NBT.B.7
Add, subtract, multiply, and divide decimals to hundredths, using concrete models or drawings and strategies basedon place value properties of operations, and/or the relationship between addition and subtraction; relate the strategy to a written method and explain the reasoning used.
Apply and extend previous understandings of multiplication and division.
CCSS.MATH.CONTENT.5.NF.B.6
Solve real-world problems involving multiplication of fractions and mixed numbers, e.g., by using visual fractionmodels or equations to represent the problem.
Measurement and Data
Convert like measurement units within a given measurement system.
CCSS.MATH.CONTENT.5.MD.A.1
Convert among different-sized standard measurement units within a given measurement system (e.g., convert 5 cmto 0.05 m), and use these conversions in solving multi-step, real-world problems.
Reading Standards for Literature K–5Key Ideas and Details
CCSS.ELA-LITERACY.RL.5.1
Quote accurately from a text when explaining what the text says explicitly and when drawing inferences from thetext.
CCSS.ELA-LITERACY.RL.5.1
Determine a theme of a story, drama, or poem from details in the text, including how characters in a story or dramarespond to challenges or how the speaker in a poem reflects upon a topic; summarize the text.
CCSS.ELA-LITERACY.RL.5.3
Compare and contrast two or more characters, settings, or events in a story or drama, drawing on specific details inthe text (e.g., how characters interact).
Craft and Structure
CCSS.ELA-LITERACY.RL.5.4
Determine the meaning of words and phrases as they are used in a text, including figurative language such asmetaphors and similes.
Range of Reading and Level of Text Complexity
CCSS.ELA-LITERACY.RL.5.10
By the end of the year, read and comprehend literature, including stories, dramas, and poetry, at the high end of thegrades 4–5 text complexity band independently and proficiently.
Reading Standards for Informational Text K–5Key Ideas and Details
CCSS.ELA-LITERACY.RI.5.1
Quote accurately from a text when explaining what the text says explicitly and when drawing inferences from thetext.
CCSS.ELA-LITERACY.RI.5.2
Determine two or more main ideas of a text and explain how they are supported by key details; summarize the text.
CCSS.ELA-LITERACY.RI.5.3
Explain the relationships or interactions between two or more individuals, events, ideas, or concepts in a historical, scientific, or technical text based on specific information in the text.
Craft and Structure
CCSS.ELA-LITERACY.RI.5.4
Determine the meaning of general academic and domain-specific words and phrases in a text relevant to a *grade 5topic or subject area*.
Integration of Knowledge and Ideas
CCSS.ELA-LITERACY.RI.5.7
Draw on information from multiple print or digital sources, demonstrating the ability to locate an answer to aquestion quickly or to solve a problem efficiently.
Range of Reading and Level of Text Complexity
CCSS.ELA-LITERACY.RI.5.10
By the end of the year, read and comprehend informational texts, including history/social studies, science, andtechnical texts, at the high end of the grades 4–5 text complexity band independently and proficiently.
Writing Standards K–5 Text Types and Purposes
CCSS.ELA-LITERACY.W.5.2
Write informative/explanatory texts to examine a topic and convey ideas and information clearly.
CCSS.ELA-LITERACY.W.5.2.A
Introduce a topic clearly, provide a general observation and focus, and group related information logically;include formatting (e.g., headings), illustrations, and multimedia when useful to aiding comprehension.
CCSS.ELA-LITERACY.W.5.2.B
Develop the topic with facts, definitions, concrete details, quotations, or other information and examplesrelated to the topic.
CCSS.ELA-LITERACY.W.5.2.C
Link ideas within and across categories of information using words, phrases, and clauses (e.g., *in contrast,especially*).
CCSS.ELA-LITERACY.W.5.2.D
Use precise language and domain-specific vocabulary to inform about or explain the topic.
CCSS.ELA-LITERACY.W.5.2.E
Provide a concluding statement or section related to the information or explanation presented.
Production and Distribution of Writing
CCSS.ELA-LITERACY.W.5.4
Produce clear and coherent writing in which the development and organization are appropriate to task, purpose, andaudience. (Grade-specific expectations for writing types are defined in standards 1–3 above.)
CCSS.ELA-LITERACY.W.5.6
With some guidance and support from adults, use technology, including the Internet, to produce and publish writing as well as to interact and collaborate with others; demonstrate sufficient command of keyboarding skills to type a minimum of two pages in a single sitting.
Speaking and Listening Standards K–5Comprehension and Collaboration
CCSS.ELA-LITERACY.SL.5.1
Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on *grade 5 topics and texts*, building on others' ideas and expressing their own clearly.
CCSS.ELA-LITERACY.SL.5.1.A
Come to discussions prepared, having read or studied required material; explicitly draw on thatpreparation and other information known about the topic to explore ideas under discussion.
CCSS.ELA-LITERACY.SL.5.1.B
Follow agreed-upon rules for discussions and carry out assigned roles.
CCSS.ELA-LITERACY.SL.5.1.C
Pose and respond to specific questions by making comments that contribute to the discussion andelaborate on the remarks of others.
CCSS.ELA-LITERACY.SL.5.1.D
Review the key ideas expressed and draw conclusions in light of information and knowledge gained fromthe discussions.
CCSS.ELA-LITERACY.SL.5.2
Summarize a written text read aloud or information presented in diverse media and formats, including visually,quantitatively, and orally.

APPENDIX F. RENEWABLE ENERGY 1.0

Renewable Energy

Cover Page

Topic
Renewable energy

Key Question
What are ways we can harness renewable energy for use in our everyday life?

Goals
Students will:

6. Solve real-world problems using mathematical models
7. Cycle through the iterative engineering design cycle of express-test-revise
8. Engage in statistical thinking while working collaboratively
9. Make decisions about the effectiveness of a solution
10. Prepare written and verbal reports of a viable solution

Guiding Documents
This task has the potential to address some Standards for Mathematical Practices (SMPs) and Standard of Mathematics Content (SMC). However, as implementation strategies and student solutions may vary, not all standards may apply. Please see Appendix A for a complete list of Common Core State Standards (CCSS) that may apply.

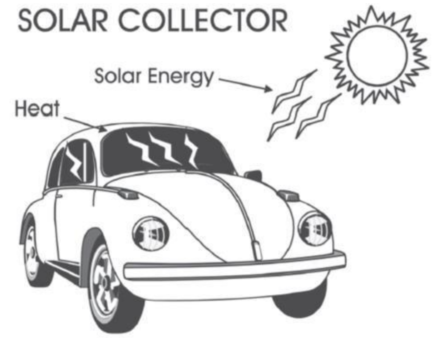
Recommended Supplies for all Modeling-Eliciting Activities
It is recommended to have all supplies in a central location in the room. In addition, it is recommended to let the students know that they are available, but not to encourage them to use specific supplies.

- TI-15 Explorer Elementary or equivalent calculators
- Standard 12-inch rulers (metric or standard units)
- Colored pencils
- Number 2 pencils
- Wide ruled composition notebooks or loose-leaf paper

Renewable Energy 1.0

Advanced Organizer / News Article

Powering the City of Indianapolis with Renewable Energy



On a sunny day, the sun heats the inside of a car and changes into heat.

What is renewable energy? Renewable energy is made from natural sources. The word renewable means that the energy source will always be available. Two sources of renewable energy are the **sun** and **wind** energy.

The energy that comes from the sun is called solar energy. The word solar means sun. Solar energy can be used to heat homes, buildings, and water. One example of solar energy is when the sun heats the inside of a car on a hot sunny day.

Indianapolis has the world's largest solar farm. In 2014, the Indianapolis International Airport became the world's largest solar energy farm. The farm covers 183 acres of land. One acre is 43, 560 square feet. One acre is the size of Purdue University's football field. The farm uses 87,488 solar panels. Solar panels like those in the picture use the sun to make energy. That energy turns into electrical power, which is also known as electricity. That electricity can power about 12,500 homes. The city of Indianapolis has 38 other solar farms. These solar farms make about 100 megawatts (MW) of power. A megawatt is equal to 106 watts. Each light bulb that we have in our home uses about 40 watts.

Indianapolis Airport Solar Farm

Wind energy is made when air blows through wind turbines like the ones in the picture. The wind turns the blades of the wind turbine to produce electricity. The wind must blow at 15 miles per hour (MPH) or faster to make wind energy. Cars drive 15 MPH in front of schools. One wind turbine can produce enough electricity for 300 homes for one year. Indiana has one of the largest wind farms in the world, located in Fowler Ridge county. The Fowler Ridge wind farm can make 750 MW of power. Indiana has ten wind farms in total.

Wind Turbines

Solar and wind energy is the renewable energy of the future. Indiana is powering the city of Indianapolis with solar and wind energy. Many people that live and work in Indianapolis are very excited to use solar and wind energy. However, some people have questions about renewable energy. Which renewable energy is cheaper or makes the most energy? Which renewable energy source uses less land space? Do the renewable energy sources impact birds that fly near the turbines? Scientists at Purdue and City Planners are working hard to answer these questions.

Renewable Energy 1.0

Readiness Questions I / Discussion Topics

1. How would you define renewable energy?
2. What are two or more ways that renewable energy is generated?
3. Why do you think Indiana and other states are interested in wind and solar energy farms?
4. How fast must the wind blow to generate wind energy?
5. What do you think happens if the wind blows less than the required speeds?
6. What questions do you have about wind and solar energy?

Readiness Questions II / Discussion Topics

1. One wind turbine generates 4MW of power. How many wind turbines are needed for a factory that uses 100MW of power?

2. One solar panel generates 0.4MW of power per acre. One solar panel costs $1 million per acre. How much does it cost to generate 4MW?

3. One home needs 0.005 MW of power. How many homes can be powered by a wind turbine farm that generates 12MW of power?

4. A solar panel farm generates 0.3MW per acre. So how many MW of power can 15 acres generate?

5. One acre of wind turbines costs $975,000. So how much would it cost to put wind turbines on 70 acres?

Renewable Energy 1.0

Problem Statement

To: Cold Springs's Students
From: Dr. Renee Carter, Director of City Planning, Power Division
Subject: Converting our city to renewable energy by 2030

As the Director of City Planning, I am responsible for ensuring that the city of Indianapolis is fully powered by ***renewable energy*** by 2030. First, we must decide to install wind turbines or solar panels to supply the city with 200 Megawatts (MW) of power. The city has 500 million dollars to spend and 1000 acres of land to use.

We need you to create a procedure that can tell us how many wind turbines or solar panels are required to buy and install. There are four brands of wind turbines and four brands of solar panels. You can use as many brands of wind turbines or solar planes as you want. Use the attached datasets to help you create your procedure.

You might think of the following questions as your team works on solving the problem**:**

a. How many turbines or solar panels are needed to meet the city's power needs?
b. What is the least amount of land needed to meet the city's power needs?
c. What is the lowest cost of turbines or solar panels that supply 200 MW of power?

Write a letter using complete sentences to address the following 4 points.

1. Describe your procedure in detail.
2. How did you decide on the number of wind turbines or solar panels?
3. What was more important in your decision-making, cost, or land use?
4. Would it make sense to use both wind turbines and solar panels?

Take notes on your procedure development progress along the way. You should include some of your notes in the letter. Also, different ideas (correct or incorrect) are valuable. They are evidence of what works and what doesn't work.

Thank you,

Dr. Renee Carter

Define the Problem

1. Who is the client?

2. What problem does the client need you to solve? Explain why this problem is important to solve. Use information from your client memo to support your reasons.

3. What are three questions you want to ask the client to help you understand the problem better?

4. What will limit how you can solve the problem?

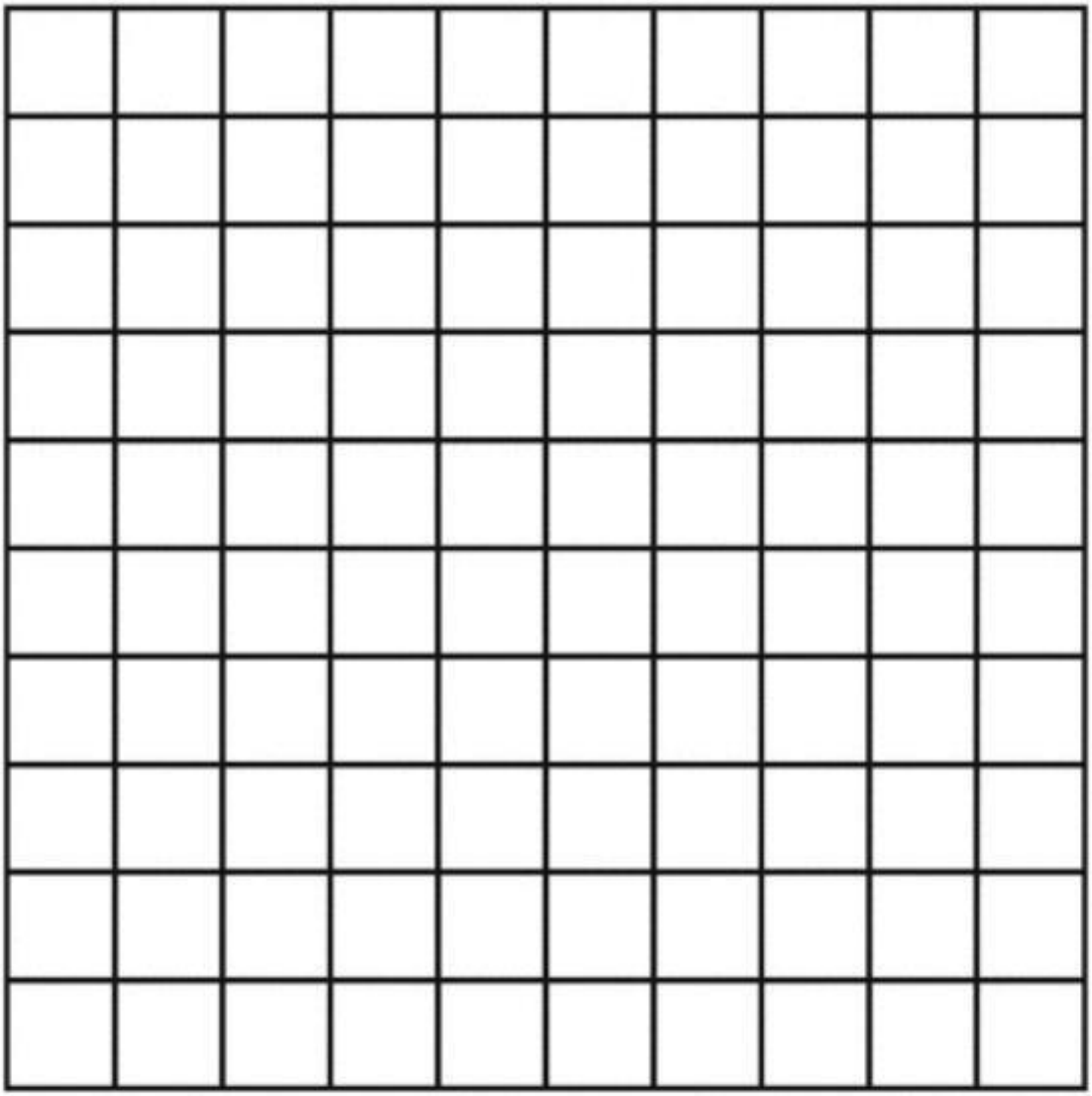
5. What are three things you need to learn to solve the problem?

Solar Panel and Wind Turbine Data Sets

Solar Panel Brand	Power in MW Per Acre	Cost Per Acre	Land Space Usage
MPI Solar	0.2 MW	$500,000	1 acre
Nusun Solar	0.1 MW	$300,000	1 acre
Sunshine Solar	0.2 MW	$500,000	1 acre
Earth Solar	0.1 MW	$300,000	1 acre

Wind Turbine Brand	Power in MW Per Acre	Cost Per Acre	Land Space Usage
Windstream	3 MW	$1,800,000	2 acres
IEA Energy	1 MW	$800,000	2 acres
Clipper Wind	2 MW	$900,000	1 acre
United Wind	0.5 MW	$400,000	1 acre

Land Space Grid



Making Healthy Food Choices 1.0

Common Core State Standards Potential Addressed

CCSS.MATH.CONTENT.5.OA.A.2
Write simple expressions that record calculations with numbers and interpret numerical expressions without evaluating them. *For example, express the calculation "add 8 and 7, then multiply by 2" as 2 × (8 + 7). Recognize that3 × (18932 + 921) is three times as large as 18932 + 921, without having to calculate the indicated sum or product.*
Number and Operations in Base TenUnderstand the place value system.
Perform operations with multi-digit whole numbers and with decimals to hundredths.
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Add, subtract, multiply, and divide decimals to hundredths, using concrete models or drawings and strategies basedon place value properties of operations, and/or the relationship between addition and subtraction; relate the strategy to a written method and explain the reasoning used.
Apply and extend previous understandings of multiplication and division.
CCSS.MATH.CONTENT.5.NF.B.6
Solve real-world problems involving multiplication of fractions and mixed numbers, e.g., by using visual fractionmodels or equations to represent the problem.
Measurement and Data
Convert like measurement units within a given measurement system.
CCSS.MATH.CONTENT.5.MD.A.1
Convert among different-sized standard measurement units within a given measurement system (e.g., convert 5 cmto 0.05 m), and use these conversions in solving multi-step, real-world problems.
Reading Standards for Literature K–5Key Ideas and Details
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Quote accurately from a text when explaining what the text says explicitly and when drawing inferences from thetext.
CCSS.ELA-LITERACY.RL.5.1
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CCSS.ELA-LITERACY.RL.5.3
Compare and contrast two or more characters, settings, or events in a story or drama, drawing on specific details inthe text (e.g., how characters interact).
Craft and Structure
CCSS.ELA-LITERACY.RL.5.4
Determine the meaning of words and phrases as they are used in a text, including figurative language such asmetaphors and similes.
Range of Reading and Level of Text Complexity
CCSS.ELA-LITERACY.RL.5.10
By the end of the year, read and comprehend literature, including stories, dramas, and poetry, at the high end of thegrades 4–5 text complexity band independently and proficiently.
Reading Standards for Informational Text K–5Key Ideas and Details
CCSS.ELA-LITERACY.RI.5.1
Quote accurately from a text when explaining what the text says explicitly and when drawing inferences from thetext.
CCSS.ELA-LITERACY.RI.5.2
Determine two or more main ideas of a text and explain how they are supported by key details; summarize the text.
CCSS.ELA-LITERACY.RI.5.3
Explain the relationships or interactions between two or more individuals, events, ideas, or concepts in a historical, scientific, or technical text based on specific information in the text.
Craft and Structure
CCSS.ELA-LITERACY.RI.5.4
Determine the meaning of general academic and domain-specific words and phrases in a text relevant to a *grade 5topic or subject area*.
Integration of Knowledge and Ideas
CCSS.ELA-LITERACY.RI.5.7
Draw on information from multiple print or digital sources, demonstrating the ability to locate an answer to aquestion quickly or to solve a problem efficiently.
Range of Reading and Level of Text Complexity
CCSS.ELA-LITERACY.RI.5.10
By the end of the year, read and comprehend informational texts, including history/social studies, science, andtechnical texts, at the high end of the grades 4–5 text complexity band independently and proficiently.
Writing Standards K–5 Text Types and Purposes
CCSS.ELA-LITERACY.W.5.2
Write informative/explanatory texts to examine a topic and convey ideas and information clearly.
CCSS.ELA-LITERACY.W.5.2.A
Introduce a topic clearly, provide a general observation and focus, and group related information logically;include formatting (e.g., headings), illustrations, and multimedia when useful to aiding comprehension.
CCSS.ELA-LITERACY.W.5.2.B
Develop the topic with facts, definitions, concrete details, quotations, or other information and examplesrelated to the topic.
CCSS.ELA-LITERACY.W.5.2.C
Link ideas within and across categories of information using words, phrases, and clauses (e.g., *in contrast,especially*).
CCSS.ELA-LITERACY.W.5.2.D
Use precise language and domain-specific vocabulary to inform about or explain the topic.
CCSS.ELA-LITERACY.W.5.2.E
Provide a concluding statement or section related to the information or explanation presented.
Production and Distribution of Writing
CCSS.ELA-LITERACY.W.5.4
Produce clear and coherent writing in which the development and organization are appropriate to task, purpose, andaudience. (Grade-specific expectations for writing types are defined in standards 1–3 above.)
CCSS.ELA-LITERACY.W.5.6
With some guidance and support from adults, use technology, including the Internet, to produce and publish writing as well as to interact and collaborate with others; demonstrate sufficient command of keyboarding skills to type a minimum of two pages in a single sitting.
Speaking and Listening Standards K–5Comprehension and Collaboration
CCSS.ELA-LITERACY.SL.5.1
Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on *grade 5 topics and texts*, building on others' ideas and expressing their own clearly.
CCSS.ELA-LITERACY.SL.5.1.A
Come to discussions prepared, having read or studied required material; explicitly draw on thatpreparation and other information known about the topic to explore ideas under discussion.
CCSS.ELA-LITERACY.SL.5.1.B
Follow agreed-upon rules for discussions and carry out assigned roles.
CCSS.ELA-LITERACY.SL.5.1.C
Pose and respond to specific questions by making comments that contribute to the discussion andelaborate on the remarks of others.
CCSS.ELA-LITERACY.SL.5.1.D
Review the key ideas expressed and draw conclusions in light of information and knowledge gained fromthe discussions.
CCSS.ELA-LITERACY.SL.5.2
Summarize a written text read aloud or information presented in diverse media and formats, including visually,quantitatively, and orally.

APPENDIX G. URBAN GREEN SPACES 1.0

Urban Green Spaces 1.0

Cover Page

Topic
Urban green space development to engage and empower residents in local communities.

Key Questions
How do design and access to green spaces influence the quality of life for residents in urban neighborhoods?

Goals
Students will:
1. Solve real-world problems using mathematical models
2. Cycle through the iterative engineering design cycle of express-test-revise
3. Engage in statistical thinking while working collaboratively
4. Make decisions about the effectiveness of a solution
5. Prepare written and verbal reports of a viable solution

Guiding Documents
This MEA is aligned with selected Standards for Mathematical Practices (SMPs) and Standards of Mathematics Content (SMC). However, as implementation strategies and student solutions may vary, not all standards may apply. Please see Appendix A for a complete list of Common Core State Standards (CCSS) that may apply.

Team Formation
Essential elements for compelling cooperative learning experiences, the elimination of nonparticipation, and providing accountability for students to work effectively in completing tasks as a team include:
- Creating small teams of 4 students for the duration of the MEA. Advise students that they cannot change teams
- Establishing individual accountability by assessing students both individually and as a team
- Building interdependence by assigning team roles and interdependent tasks - The team can only complete the MEA if all members perform their tasks

Recommended Supplies for all Modeling-Eliciting Activities
It is recommended to have all supplies in a central location in the room. In addition, it is recommended to let the students know that they are available, but not to encourage them to use specific supplies.
1. TI-15 Explorer Elementary or equivalent calculators
2. Standard 12-inch rulers (metric or standard units; rulers should be consistent across classroom usage)
3. Colored pencils
4. Number 2 pencils
5. Wide ruled composition notebooks or loose-leaf paper

Urban Green Spaces 1.0

Advanced Organizer / New Article

Green spaces are areas of land covered with grass, trees, shrubs, flowers, or other vegetation. Examples of green spaces include community gardens, lawns, bike trails, picnic areas, playgrounds, andwetlands. Green spaces are helpful to urban residents. For example, trees help keep urban areas cool by providing shade, improving air quality, reducing stormwater runoff, and promoting sociability. Sociability is a space where community members can hang out.

The majority of the world's population lives in urban cities. The urban populations in the world continue to grow. Urban residents should haveaccess to green spaces within a 10-minute walk from home. Research shows that people who regularly use parks get more exercise than people who don't. Exercise can improve quality of life. Unfortunately, not all urban residents have fair access to green spaces. Less than of 3 percent Indianapolis residents live within a 10-minute walk to green space.

In 2015, Indianapolis Parks began updating its "green spaces plan" by holding local meetings. Residents from all Indianapolis neighborhoods engaged in discussions about planning and designing green spaces in their communities. Each community developed a plan for a greenspace in their neighborhood. Plans had four parts. First, community members listed various green space types like gardens or trails they desired for their neighborhood. Second, they wrote the strengths and weaknesses of those green space features. Third, based on the strengths and weaknesses written earlier, they decided on green space types that were a priority for their neighborhood. Finally, they considered costs for each green space type and the maintenance neededduring the year.

Guided Questions Set 1

A. What neighborhoods within Indianapolis might have more green space than other neighborhoods?

B. How might cities like Indianapolis determine what neighborhoods get more green spaces, like parks?

Guided Questions Set 2

A. Can you think of a neighborhood that could use more green space?

B. What are some reasons why a neighborhood might need more green space?

Problem Statement

MEMORANDUM

To:	Students of Cold Spring Elementary
From:	Liz Crawford, Program Manager of 2020 Keep Indianapolis Beautiful (KIB)
Subject:	Funding Green Space Projects

The KIB Green Space Program was created to help transform vacant lots and underused spaces into natural, beautiful, and functional green spaces. We work with community groups in Indianapolis. We award up to $1,000 to fund green space projects. Green space projects include creating or cleaning small community gardens, pollinator gardens, curbside green spaces with native plants, art parks, small pocket parks, small playgrounds, and picnic areas.

We need your help to design a green space for a community that has submitted an application packet for a $1,000 green space grant. We have provided you two application packets for green space. The application packet contains four parts: (1) Community Description, (2) Project Importance, Space Vision, and (4) Maintenance Plan. A data table given to applicants explains each of the four parts. We have also provided you a green space materials cost sheet. The materials cost sheet lists materials and their cost associated with each application. Each team member in your group is responsible for completing a specific job related to the application. We provide a description of team member job titles and responsibilities.

<u>Here is what we need you to do:</u>
Your first goal: Read each of the four items in each application packet. Choose a community green space project to design.

Your second goal: Design a green space according to the details in the application packet. The design must include all of the elements of your chosen application packet. You will need to make a drawing to showcase your design.

Your third goal: Create a budget for all materials used in your design. Please include all of your calculationsfor the budget. For example. 4 large bags of soil at $4.28 each = $17.12 total.

Your fourth goal: Create a poster that shows:

1. A design model of your green space.
2. An explanation of why your design model fits the community's needs. For example, what did you read in the application packet that influenced your design? What are some things in your design that can be made differently? What limited your design? What other designs did you consider? Why didyou not propose those designs?
3. Include your budget and all calculations in your poster.

Your green space design may become a model for designing future KIB green spaces.

Thank you

Liz Crawford, Program Manager

Urban Green Spaces 1.0

Define the Problem

1. Who is the client that has requested your help?

2. What problem does the client need you to solve?

3. What will you need to provide the client?

Urban Green Spaces 1.0

Team Roles and Responsibilities

Team Roles	**Team Responsibility**
Project Manager	The Project Manager is responsible for making sure the project is completed on time. You will check in with your team members throughout the project to see if they need support. You will also keep detailed notes so that you can write the answers to the questions posted under your final goal in this memo for the final presentation.
Space Designer	The Space Designer will design the green space according to the community's request. You will work with the Financial Manager who will tell you what green space equipment can be purchased to stay within the budget. You will draw the space and indicate where the green space equipment will be installed for the final presentation
Financial Manager	The Financial Manager will work with the Space Designer to determine what green space equipment can be purchased to stay within the budget. Then, you will calculate the cost of equipment that the Space Designer is requesting. You will also complete the budget session of your final presentation.
Communication Manager	The Presentation Manager will make sure that the final poster presentation is completed according to the application. Next, you will make sure the poster is complete. You will organize the final presentation by organizing your teammates up to present their parts for the poster.

Urban Green Spaces 1.0

KIB Community Project Data Table

Item	Item Description
Community Description	The *community description* describes the condition of the community. Information includes the population size, neighborhood size, *tree cover data, crime rate, income rate, and the *walkability score. * means that you should see a note below for more information.
Project Importance	The *project's importance* includes the location of the community's greenspace. It also explains the importance of green space to the community. This section also describes how the project enhances the community. For example, some projects may rebuild a park to include a pollinator garden or a vegetable garden. Some green spaces might increase sociability where community members can interact and get to know each other.
Space Vision	The *space vision* explains the design for the green space in the community. The space vision also describes how the community will use the green space and what type of equipment the community wants in the green space.
Maintenance Plan	The *maintenance plan* communicates how the community plans to maintain the green space once the project is complete.

*Tree cover data tells us the percentage of land with tree canopy coverage.
Why is tree cover data important? Sufficient tree canopy coverage has several positive impacts:improved air quality, decreased summer cooling costs, natural stormwater drainage, and aesthetic value.

*Walkability score tells us how walkable a neighborhood is based on the presence of sidewalks,intersections, and public transportation.

Why is the walkability score important? Walkability is important to residents' health and well-beingand is also related to the desirability of areas for many demographic groups, particularly younger generations. It is also important to the inclusiveness of a community to persons with disabilities and the ability to support storefront-type retail.

Urban Green Spaces 1.0

Green Space Materials Cost Sheet and Budget

Item	Quantity	Price	Quantity	x	Price	Total	Comments
Wood for garden beds (4 x 8)	4 planks a pack	5.52		x			
Soil	1 large bag	4.28		x			
Flower seeds	1 pack	1.58		x			
Tomato seeds	1 pack	2.73		x			
Cucumber seeds	1 pack	.58		x			
Carrot seeds	1 pack	2.49		x			
Garden tool set	1 set	16.51		x			
Water hose	1, 50 feet long	29.97		x			
Grass	1, 20-pound bag	26.66		x			
Mulch	1 large bag	3.33		x			
Shade tree (redwood)	1	29.98		x			
Park bench & table set	1 (fit 8 people)	75.00		x			
Swing Set	1 (fit 5 people)	0.00		x			Donation from Indianapolis
Merry-go-round	1 (fit 5 people)	0.00		x			Donation from Indianapolis
Outdoorcooking equipment	1 unit	40.00		x			
Picnic area shelter	1 unit (fit 50)	0.00		x			Donation from Indianapolis
Removal of debris	1 to 3 miles	200.00		x			
Gravel	1 to 3 miles	50.00		x			
Green space signage	1	75.00		x			
Volunteers	Indicate how many volunteers	0.00		x			
Maintenance	Explain your maintenance plan.			x			

BudgetTotals	**Total Amount Green Space Grant**	**Total Cost of Materials**	**Remaining Balance**

Urban Green Spaces 1.0

Community Green Space Application Packets

Rivoli Park Neighborhood Application

Community Description

Rivoli Park neighborhood in Indianapolis was once a vibrant community; the near east side in Indianapolis was drastically affected by the economic downfall in 2008. As a result, the near east side has experienced a rise in crimes and abandoned houses. This hard-working community faces financial instability and is hoping that through the support of the KIB grant, they can transform a vacant lot into a park.

Project Importance

The park will create a green space for neighborhood socializing and for children to play and explore. This project will also create a green space for all community members to enjoy. The green space will help reestablish the neighborhood as a safe and friendly place for families and help rebuild a community. The new park will be the community's first and only park within a 10-minute walk for Rivoli Park residents.

Space Vision

The park is envisioned as a green space that will include tables and benches for socializing. The space will include playground equipment where children can play and where adults can come together to socialize. The green spacewill also serve the community as a site for neighborhood birthday parties, church cookouts, and a community meeting space.

Maintenance Plan

The community plans to organize a volunteer schedule where neighbors rotate mowing, pick up trash, and make sure the park equipment is working properly. In addition, Rivoli Park residents have agreed to donate $15.00 per year formaintenance costs.

Ransom Place Neighborhood Application

Community Description

This once-thriving community, the Ransom Place neighborhood, has undergone several hardships. Surrounded by Indiana University – Purdue University Indianapolis, the Ransom Place neighborhood has often been overlooked by theIndianapolis Parks Association. As a result, one of the two parks in this large neighborhood is no longer in safe working condition. This large family-oriented community hopes to rebuild the non-working park to make a safe green space for the community.

Project Importance

The green space will establish a safe and fun area in the community where Ransom Place neighbors can gathertogether to celebrate good times and work together to enhance the neighborhood. The new green space will increase neighborhood pride.

Space Vision

The community has voted to rebuild the non-working park. The community would like to see the park gain a newsign, playground equipment, tables, benches, and grass and mulch.

Maintenance Plan

The community organized a volunteer schedule where neighbors will rotate mowing, picking up trash, and making sure the park equipment is working properly. Ransom Place residents have agreed to donate $5.00 a year for maintenance costs.

Urban Green Spaces 1.0

Common Core State Standards Potentially Addressed

Geometry K-4
CCSS.MATH.CONTENT.4.G.A.1
Draw points, lines, line segments, rays, angles (right, acute, obtuse), and perpendicular and parallel lines. Identify these in two-dimensional figures.
Math Standards for Operations & Algebraic Thinking K-5Number and Operations in Base Ten
Understand the place value system.
Perform operations with multi-digit whole numbers and with decimals to hundredths.
CCSS.MATH.CONTENT.5.NBT.B.7
Add, subtract, multiply, and divide decimals to hundredths, using concrete models or drawings and strategies based on place value properties of operations, and/or the relationship between addition and subtraction; relate the strategy to a written method and explain the reasoning used.
Apply and extend previous understandings of multiplicationand division.
CCSS.MATH.CONTENT.5.NF.B.6
Solve real-world problems involving multiplication of fractions andmixed numbers, e.g., by using visual fraction models or equations to represent the problem.
Measurement and Data
Convert like measurement units within a given measurement system.
CCSS.MATH.CONTENT.5.MD.A.1
Convert among different-sized standard measurement units within agiven measurement system (e.g., convert 5 cm to 0.05 m), and use these conversions in solving multi-step, real-world problems.
Reading Standards for Literature K–5Key Ideas and Details
CCSS.ELA-LITERACY.RL.5.1
Quote accurately from a text when explaining what the text says explicitly and when drawing inferences from the text.
Range of Reading and Level of Text Complexity
CCSS.ELA-LITERACY.RL.5.10
By the end of the year, read and comprehend literature, including stories, dramas, and poetry, at the high end of the grades 4–5 text complexity band independently and proficiently.
Reading Standards for Informational Text K–5 Key Ideas and Details
CCSS.ELA-LITERACY.RI.5.1
Quote accurately from a text when explaining what the text says explicitly and when drawing inferences from the text.
CCSS.ELA-LITERACY.RI.5.2
Determine two or more main ideas of a text and explain how they are supported by key details; summarize the text.
CCSS.ELA-LITERACY.RI.5.3
Explain the relationships or interactions between two or more individuals, events, ideas, or concepts in a historical, scientific, or technical text based on specific information in the text.
Craft and Structure
CCSS.ELA-LITERACY.RI.5.4
Determine the meaning of general academic and domain-specific words and phrases in a text relevant to a *grade 5 topic or subject area*.
Integration of Knowledge and Ideas
CCSS.ELA-LITERACY.RI.5.7
Draw on information from multiple print or digital sources, demonstrating the ability to locate an answer to a question quickly or to solve a problem efficiently.
Range of Reading and Level of Text Complexity
CCSS.ELA-LITERACY.RI.5.10
By the end of the year, read and comprehend informational texts, including history/social studies, science, and technical texts, at the high end of the grades 4–5 text complexity band independently and proficiently.
Writing Standards K–5 Text Types and Purposes
CCSS.ELA-LITERACY.W.5.2
Write informative/explanatory texts to examine a topic and convey ideas and information clearly.
CCSS.ELA-LITERACY.W.5.2.A
Introduce a topic clearly, provide a general observationand focus, and group related information logically; include formatting (e.g., headings), illustrations, and multimedia when useful to aiding comprehension.
CCSS.ELA-LITERACY.W.5.2.B
Develop the topic with facts, definitions, concrete details, quotations, or other information and examplesrelated to the topic.
CCSS.ELA-LITERACY.W.5.2.C
Link ideas within and across categories of informationusing words, phrases, and clauses (e.g., *in contrast*, *especially*).
CCSS.ELA-LITERACY.W.5.2.D
Use precise language and domain-specific vocabularyto inform about or explain the topic.
CCSS.ELA-LITERACY.W.5.2.E
Provide a concluding statement or section related to theinformation or explanation presented.
Production and Distribution of Writing
CCSS.ELA-LITERACY.W.5.4
Produce clear and coherent writing in which the development and organization are appropriate to task, purpose, and audience. (Grade-specific expectations for writing types are defined in standards 1–3 above.)
Speaking and Listening Standards K–5Comprehension and Collaboration CCSS.ELA-LITERACY.SL.5.1
Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on *grade 5 topics and texts*, building on others' ideas and expressing their own clearly.
CCSS.ELA-LITERACY.SL.5.1.A
Come to discussions prepared, having read or studied required material; explicitly draw on that preparation andother information known about the topic to explore ideasunder discussion.
CCSS.ELA-LITERACY.SL.5.1.B
Follow agreed-upon rules for discussions and carry outassigned roles.
CCSS.ELA-LITERACY.SL.5.1.C
Pose and respond to specific questions by making comments that contribute to the discussion and elaborateon the remarks of others.
CCSS.ELA-LITERACY.SL.5.1.D
Review the key ideas expressed and draw conclusionsin light of information and knowledge gained from the discussions.
CCSS.ELA-LITERACY.SL.5.2
Summarize a written text read aloud or information presented in diverse media and formats, including visually, quantitatively, and orally.

APPENDIX H. FOOD SECURITY / INSECURITY 1.0

Food Security / Insecurity 1.0

Cover Page

Topic
Food security/insecurity

Key Questions
How can a community contribute to increasing the availability of healthy food?

Goals
Students will:

1. Solve real-world problems using mathematical models
2. Cycle through the iterative engineering design cycle of express-test-revise
3. Engage in statistical thinking while working collaboratively
4. Make decisions about the effectiveness of a solution
5. Prepare written and verbal reports of a viable solution

Guiding Documents
This MEA is aligned with selected Standards for Mathematical Practices (SMPs) and Standards of Mathematics Content (SMC). However, as implementation strategies and student solutions may vary, not all standards may apply. Please see Appendix A for a complete list of Common Core State Standards (CCSS) that may apply.

Team Formation

- Essential elements for compelling cooperative learning experiences, the elimination of nonparticipation, and providing accountability for students to work effectively in completing tasks as a team include:
- Creating small teams of 4 students for the duration of the MEA. Advise students that they cannot change teams
- Establishing individual accountability by assessing students both individually and as a team
- Building interdependence by assigning team roles and interdependent tasks; The team can only complete the MEA if all team members perform their individual tasks

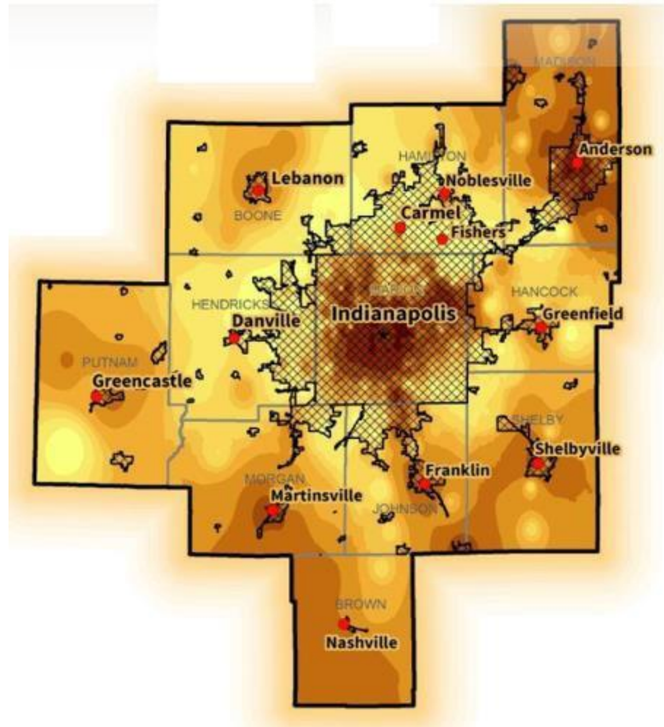
Recommended Supplies for all Modeling-Eliciting Activities
It is recommended to have all supplies in a central location in the room. In addition, it is recommended to let the students know that they are available and not encourage them to use specific supplies.

1. TI-15 Explorer Elementary or equivalent calculators
2. Standard 12-inch rulers (metric or standard units; rulers should be consistent across classroom usage)
3. Colored pencils
4. Number 2 pencils
5. Wide ruled composition notebooks or loose-leaf paper

Food Security / Insecurity

Advanced Organizer / News Article

People who live in communities with no grocery stores or farmers' markets suffer from food insecurity. The United States Department of Agriculture(USDA) defines food insecurity as a lack of consistent access to enough healthy food. Families having food insecurity may have access to food, but not healthy food.Healthy foods include fruits, vegetables, beans, potatoes, and nuts. Communities that do not have access to grocerystores are typically found in low-income areas. Food insecurity in Central Indiana's 11 counties is a growing problem. In particular, 17% of the people that live in Marion County are food insecure. More than 175,000 of the 950,000 people that live in Indianapolis suffer from food insecurity. Indianapolis has the highest rate of foodinsecurity in Indiana.



Read the entire report at: http://www.savi.org/report/hunger-in-central-indiana/

The Map to the right shows the poverty rates in Central Indiana. Poverty is the condition of having little orno money or means of support. The dark brown areas have high poverty, and the bright yellow areas have low poverty.

Many Indianapolis communities are in high poverty and are overrun with fast food and convenience stores that do not sell healthy foods.

After reading the above paragraph, discuss the guided questions under set 1 (p. 4).

Many Indianapolis communities are coming together to combat food insecurity by increasing access to healthy food for residents. For example, www.IndyHunger.org has information on nearly 200 food pantries in Indianapolis where people can access healthy food. The Indianapolis Hunger Network is also exploring ideas for making signing up for SNAP (Supplemental Nutrition Assistance Program) and WIC (Women, Infants, and Children) programs much easier. Connect2help.org is the largest information and referral contact center in Central Indiana, connecting people who need help to those who can provide help. In addition, some communities are starting food movements. A food movement is when people work together to provide healthyfood for their community. For example, fifth-grader Austin King Hurt started a community garden to help feed his familyand others who struggled with food insecurity. Austin knocked on his neighbor's door to ask if he could turn her empty lot into a community garden to provide healthy food tothe community. The neighbor agreed. Four years later, Austin's community garden efforts have turned into a healthy food movement in his community and have gained admirers such as Detroit Piston's basketball player, Glenn Robinson. If you want to learn more about Austin's garden, check out his Facebook page: @TheYoungUrbanGardener. After reading the above paragraph, discuss the guided questions under set 2 (p. 4).

Food Security / Insecurity

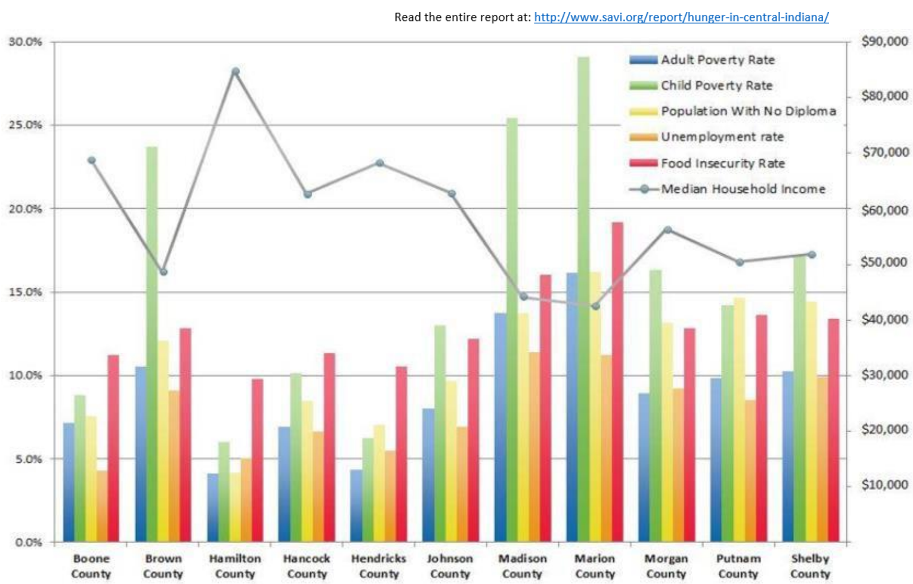
Guided Discussion Questions

Set 1

A. What are some reasons some neighborhoods have access to grocery stores and some neighborhoods do not have access to grocery stores?

- How many grocery stores are in your neighborhood?
- Do you know of any areas that have very few grocery stores?
- Why might it be difficult for people who live in low-income neighborhoods to go shopping at large grocery stores?
- Why do local convenience stores not sell fresh fruits and vegetables?

The Central Indiana Demographics chart below enables easy comparison of several variables associated with hunger: adult and child poverty, unemployment, food insecurity, median household income, and population withno diploma between each county.



Set 2

Growing your own healthy foods is one way to fight food injustice.

- What are some ways to grow healthy foods?
- What are some methods one might use to grow vegetables? (e.g., container gardens, raised beds, hydroponics, rooftops)?
- Have you or your family or friends fought food injustice by donating food to a food pantry or through a food donation drive?

How might a community work together to start and maintain a food movement?

- Which organizations have experience in gardening and raising food?
- How can people get organized to learn how to garden?
- How might urban farming/urban gardening provide food security for a community?

Food Security / Insecurity

Problem Statement

MEMORANDUM

To: Students of Cold Spring Elementary
From: Purdue University MALTS Team
Subject: Square Foot Garden Blueprints

Square Foot Gardens (SFGs) are popular because SFGs allow different kinds of vegetables and flowers to be planted close together in a small space. This results in high yields compared to other gardening techniques, like planting in rows. SFGs are also a fun science project that can last for months and help feed your family with fresh vegetables.

SFGs can take a few steps to create. First, create a rectangular garden space that can be divided into one-foot squares. An SFG is called an SFG because each square has an area measure of one square foot. Second, determine what plants you want in your SFG. It is helpful to design a model of your SFG to help you know what to plant in each square of your SFG. Third, plant your garden.

We need your help to create a model for an SFG that meets our size needs. We want the area of the SFG to be at least 17 square feet and no more than 19 square feet. We provided you with an SFG planning Grid, a Plant Spacing& Yield Data chart, and gardening tips.

Here is what we need you to do:
Each SFG design team member in your group is responsible for completing a specific job. We provided a description of team member roles and responsibilities.

- **Your first goal**: Decide on dimensions for your SFG model. Then, partition your garden bed with the correct number of 1-foot x 1-foot squares. Next, use the SFG Planning Grid to create your model. Remember our sizing needs of at least 15 square feet and no more than 25 square feet.
- **Your second goal**: Choose the plants that you want to grow and eat. Flowers in a garden can be excellent pollinatorsand keep the bugs away. Vegetables and fruits provide food for you and others. Select at least one type of flower for your SFG. Select at least three different kinds of vegetables or fruits.
- **Your third goal** is to calculate the number of pounds of vegetables or fruit that your SFG might yield per year. For example, if theaverage person eats approximately one pound of fruits and vegetables per day, then how many people might be fed by your garden?
- **Your final goal**: Create a poster that includes the following information:
    1. A drawing of your SFG planning grid.
    2. List the plant names and the correct number of plants per square foot.
    3. The number of pounds of fruits and or vegetables your SFG might yield per year.
    4. The number of people that your garden might feed.
    5. A written explanation of the following:
        a. What did you do to work through any problem you may have encountered?
        b. Why did you choose the shape and dimensions of your SFG?
        c. Why did you choose the plant species for your SFG?
        d. How do you know that your SFG design meets the dimension criteria and maximizes space?
        e. What assumptions did you make while problem-solving? Are there limitations to your SFG?

Remember, you are creating an SFG with vegetables and fruits that you would eat. So pick foods that you would eat. Your SFG model will help families in other communities create more SFGs.

Thank you,

Purdue University MALTS Team

Food Security / Insecurity

Define the Problem

1. What is the setting of the client's problem?

2. What is the goal to achieve?

3. Explain your initial idea for an SFG model?

4. List the steps (descriptions and procedures) you will use to make a good model?

5. What are the variables in your model?

6. How will you document your activity?

Food Security / Insecurity

Team Roles and Responsibilities

Team Roles	**Team Member's Name**	**Responsibility**
Project Manager		• Keep the team on track to complete the project on time • Check-in with team members to offer support • Keep detailed notes to write the explanation of your design
Project Designer		• Draft the project design according to the client's request • Work with the *Materials Manager* to determine project needs • Determine any project design materials
Materials Manager		• Work with the *Project Designer* to determine materials needed • Calculate the cost and number of materials needed • Pick up materials for the final poster
Communication Manager		• Communicate to your team how to present the final poster • Work with the *Project Manager* to write the explanation of your design • Organize your team to present the final poster

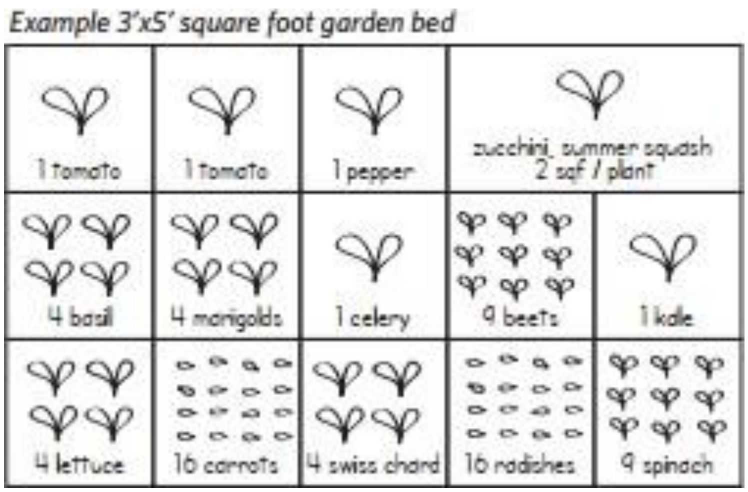
Food Security / Insecurity

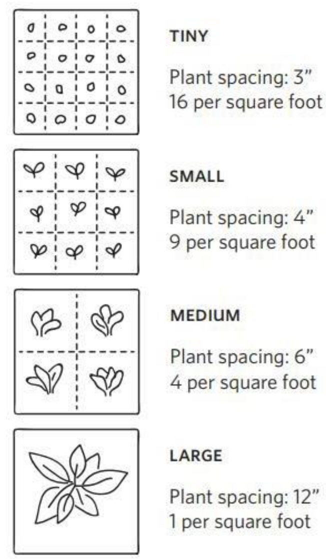
Plant Spacing and Yield Data Chart

Plant	Plants Per Square	Weeks from Seed to Harvest	Average YieldPer Square	Planting Season			
				Sp	Su	F	W
Fruit and Vegetables							
Bean	9	8	0.5 lb				
Beet	16	8	3 lbs.				
Cabbage	1	16	2 lbs.				
Carrot	16	10	3 lbs.				
Cauliflower	1	14	2 lbs.				
Corn	1	11	5 lbs.				
Cucumber	1	9	3.5 lbs.				
Eggplant	1	19	1.6 lbs.				
Kale	1	8	1.5 lbs.				
Lettuce	4	7	0.5 lb				
Onions	16	20	0.6 lb				
Snap Pea	9	10	0.5 lb				
Pepper	1	19	2.0 lbs.				
Potato	1	12	1.5 lbs.				
Spinach	9	7	0.5 lb				
Summer squash	0.5	8	4.5 lbs.				
Tomato Vine	1	17	1.5 lbs.				
Winter squash	0.5	12	4.5 lbs.				
Flowers							
Dahlia, small	4	11					
Marigold, small	4	10					
Pansy	4	20					
Petunia	4	14					
Salvia	4	14					

Square Foot Garden Tips

Mel Bartholomew coined the term "square foot gardening" (SFG) https://squarefootgardening.org/about-us/history/. This gardening practice is ideal for urban areas where space is limited. SFG is an easy way to help students learn the value of gardening in 3 simple steps: (1) Decide on the area and shape of your SFG (i.e., 15, 16, 17, etc.) ; (2) Divide your SFG into equal 1 ft x 1 ft squares; and (3) Divide each square foot into 1, 4, 9, or 16 equally spaced sections depending on the plants you choose. Each square contains one type of plant species. Each plant's required plant spacing determines the number of plants per square. The 1-foot squares to the right illustrate plant spacing. For Example, 3-inch plant spacing = 16 plants per square foot, 4-inch plant spacing = 9 plants per square foot, 6-inchplant spacing = 4 plants per square foot, and 12-inch plant spacing = 1 plant per square foot. The image of the SFG tothe left illustrates an SFG with an area of 15 square feet





One fun activity is to engage in a discussion about plant compatible and determinate versus indeterminateplant species. See the chart below for examples of plant compatibility.

Vegetable	Compatible with	
Beans	Cabbage family, carrot, corn, cucumber, eggplant, peas, potato, Swiss chard, celery	**Borage, lovage, marigold, nasturtium, oregano, summer savory, petunia, rosemary**
Beets	Bush beans, cabbage family, lettuce, onion	**Garlic**
Cabbage family*	Beets, cucumber, lettuce, onion, potato, spinach, Swiss chard	**Chamomile, dill, garlic, nasturtium, sage, thyme, rosemary**
Carrot	Beans, lettuce, onion, peas, peppers, tomato	**Chives, rosemary, sage, thyme**
Corn	Beans, cucumber, melon, peas, potato, squash, pumpkins	**Marigold, parsley**
Cucumber	Beans, broccoli, cabbage family, corn, lettuce	**Marigold, parsley, nasturtium**
Eggplant	Beans, peppers	**Marigold, thyme**
Lettuce	Beet, cabbage family, carrot, onion	**Chive, dill, garlic**
Melon	Corn, pumpkin, squash	**Marigold, nasturtium, oregano**
Onion	Beets, celery	**Chamomile, savory**
Peas	Beans, carrot, corn, cucumber, turnip	**Parsley**
Peppers	Carrot, eggplant, onion	**Basil, parsley, petunia, marjoram**
Spinach	Cabbage family, lettuce, pea, radish, celery	**Onion, strawberry, borage, lettuce**
Squash	Corn, melon, onion, pumpkin, radish	**Borage, marigold, nasturtium, oregano**
Tomato	Asparagus, beans, carrot, cucumber, onion, eggplant, broccoli	**Basil, bee balm, borage, calendula, chive, parsley, sage, thyme, marigold**

Food Security / Insecurity

Square Foot Garden Gride

Food Security / Insecurity

Common Core State Standards Potentially Addressed

Geometry K-4
CCSS.MATH.CONTENT.4.G.A.1
Draw points, lines, line segments, rays, angles (right, acute, obtuse), and perpendicular and parallel lines. Identify these in two-dimensional figures.
Math Standards for Operations & Algebraic Thinking K-5Number and Operations in Base Ten
Understand the place value system.
Perform operations with multi-digit whole numbers and with decimals to hundredths.
CCSS.MATH.CONTENT.5.NBT.B.7
Add, subtract, multiply, and divide decimals to hundredths, using concrete models or drawings and strategies based on place value properties of operations, and/or the relationship between addition and subtraction; relate the strategy to a written method and explain the reasoning used.
Apply and extend previous understandings of multiplicationand division.
CCSS.MATH.CONTENT.5.NF.B.6
Solve real-world problems involving multiplication of fractions andmixed numbers, e.g., by using visual fraction models or equations to represent the problem.
Measurement and Data
Convert like measurement units within a given measurement system.
CCSS.MATH.CONTENT.5.MD.A.1
Convert among different-sized standard measurement units within agiven measurement system (e.g., convert 5 cm to 0.05 m), and use these conversions in solving multi-step, real-world problems.
Reading Standards for Literature K–5Key Ideas and Details
CCSS.ELA-LITERACY.RL.5.1
Quote accurately from a text when explaining what the text says explicitly and when drawing inferences from the text.
Range of Reading and Level of Text Complexity
CCSS.ELA-LITERACY.RL.5.10
By the end of the year, read and comprehend literature, including stories, dramas, and poetry, at the high end of the grades 4–5 text complexity band independently and proficiently.
Reading Standards for Informational Text K–5 Key Ideas and Details
CCSS.ELA-LITERACY.RI.5.1
Quote accurately from a text when explaining what the text says explicitly and when drawing inferences from the text.
CCSS.ELA-LITERACY.RI.5.2
Determine two or more main ideas of a text and explain how they are supported by key details; summarize the text.
CCSS.ELA-LITERACY.RI.5.3
Explain the relationships or interactions between two or more individuals, events, ideas, or concepts in a historical, scientific, or technical text based on specific information in the text.
Craft and Structure
CCSS.ELA-LITERACY.RI.5.4
Determine the meaning of general academic and domain-specific words and phrases in a text relevant to a *grade 5 topic or subject area*.
Integration of Knowledge and Ideas
CCSS.ELA-LITERACY.RI.5.7
Draw on information from multiple print or digital sources, demonstrating the ability to locate an answer to a question quickly or to solve a problem efficiently.
Range of Reading and Level of Text Complexity
CCSS.ELA-LITERACY.RI.5.10
By the end of the year, read and comprehend informational texts, including history/social studies, science, and technical texts, at the high end of the grades 4–5 text complexity band independently and proficiently.
Writing Standards K–5 Text Types and Purposes
CCSS.ELA-LITERACY.W.5.2
Write informative/explanatory texts to examine a topic and convey ideas and information clearly.
CCSS.ELA-LITERACY.W.5.2.A
Introduce a topic clearly, provide a general observationand focus, and group related information logically; include formatting (e.g., headings), illustrations, and multimedia when useful to aiding comprehension.
CCSS.ELA-LITERACY.W.5.2.B
Develop the topic with facts, definitions, concrete details, quotations, or other information and examplesrelated to the topic.
CCSS.ELA-LITERACY.W.5.2.C
Link ideas within and across categories of informationusing words, phrases, and clauses (e.g., *in contrast*, *especially*).
CCSS.ELA-LITERACY.W.5.2.D
Use precise language and domain-specific vocabularyto inform about or explain the topic.
CCSS.ELA-LITERACY.W.5.2.E
Provide a concluding statement or section related to theinformation or explanation presented.
Production and Distribution of Writing
CCSS.ELA-LITERACY.W.5.4
Produce clear and coherent writing in which the development and organization are appropriate to task, purpose, and audience. (Grade-specific expectations for writing types are defined in standards 1–3 above.)
Speaking and Listening Standards K–5Comprehension and Collaboration CCSS.ELA-LITERACY.SL.5.1
Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on *grade 5 topics and texts*, building on others' ideas and expressing their own clearly.
CCSS.ELA-LITERACY.SL.5.1.A
Come to discussions prepared, having read or studied required material; explicitly draw on that preparation andother information known about the topic to explore ideasunder discussion.
CCSS.ELA-LITERACY.SL.5.1.B
Follow agreed-upon rules for discussions and carry outassigned roles.
CCSS.ELA-LITERACY.SL.5.1.C
Pose and respond to specific questions by making comments that contribute to the discussion and elaborateon the remarks of others.
CCSS.ELA-LITERACY.SL.5.1.D
Review the key ideas expressed and draw conclusionsin light of information and knowledge gained from the discussions.
CCSS.ELA-LITERACY.SL.5.2
Summarize a written text read aloud or information presented in diverse media and formats, including visually, quantitatively, and orally.

APPENDIX I. URBAN GREEN SPACES 2.0

Urban Green Spaces 2.0

Cover Page

Topic
Urban green space development to engage and empower residents in local communities.

Key Questions
How do design and access to green space influence the quality of life for residents in urban neighborhoods?

Goals

Students will:

1. Solve real-world problems using mathematical models
2. Cycle through the iterative engineering design cycle of express-test-revise
3. Engage in statistical thinking while working collaboratively
4. Make decisions about the effectiveness of a solution
5. Prepare written and verbal reports of a viable solution

Guiding Documents
This MEA is aligned with selected Standards for Mathematical Practices (SMPs) and Standards of Mathematics Content (SMC). However, as implementation strategies and student solutions may vary, not all standards may apply. Please see Appendix A for a complete list of Common Core State Standards (CCSS) that may apply.

Team Formation
Essential elements for compelling cooperative learning experiences, the elimination of nonparticipation, and providing accountability for students to work effectively in completing tasks as a team include:

- Creating small teams of 4 students for the duration of the MEA. Advise students that they cannot change teams
- Establishing individual accountability by assessing students both individually and as a team
- Building interdependence by assigning team roles and interdependent tasks; The team can only complete the MEA if all team members perform their individual tasks

Recommended Supplies for all Modeling-Eliciting Activities
It is recommended to have all supplies in a central location in the room. In addition, it is recommended to let the students know that they are available, but not to encourage them to use specific supplies.

1. TI-15 Explorer Elementary or equivalent calculators
2. Standard 12-inch rulers (metric or standard units; rulers should be consistent across classroom usage)
3. Colored pencils
4. Number 2 pencils
5. Wide ruled composition notebooks or loose-leaf paper

Urban Green Spaces 2.0

Advanced Organizer / News Article

Green spaces are areas of land covered with grass, trees, shrubs, flowers, or other vegetation. Examples of green spaces include community gardens, lawns, bike trails, picnic areas, playgrounds, and wetlands. Green spaces are helpful to urban residents. For example, trees help keep urban areas cool by providing shade, improving air quality, reducing stormwater runoff, and promoting sociability. Sociability is a space where community members can hang out.

The majority of the world's population lives in urban cities. The urban populations in the world continue to grow. Urban residents should have access to green spaces within a 10-minute walk from home. Research shows that people who regularly use parks get more exercise. Exercise can improve quality of life. Unfortunately, not all urban residents have fair access to green spaces. Less than $\frac{1}{3}$ of Indianapolis, residents live within a 10-minute walk to green space.

In 2015, Indianapolis Parks began updating its "green spaces plan" by holding local meetings. Residents from all Indianapolis neighborhoods engaged in discussions about planning and designing green spaces in their communities. Each community developed a plan for a green space in their neighborhood. Plans had four parts. First, community members listed various green space types like gardens or trails they desired for their neighborhood. Second, they wrote the strengths and weaknesses of those green space features. Third, based on the strengths and weaknesses written earlier, they decided on green space types that were a priority for their neighborhood. Finally, they considered costs for each green space type and the maintenance needed during the year.

Urban Green Spaces 2.0

Problem Statement

MEMORANDUM

To:	Students of Cold Spring Elementary
From:	Marie Clark, Program Manager of 2020 Keep Indianapolis Beautiful (KIB)
Subject:	Funding Green Space Projects

The KIB Green Space Program was created to help transform vacant lots and underused spaces into natural, beautiful, and functional green spaces. We work with community groups in Indianapolis; we award up to $1,000 to fund green space projects. Green space projects include creating or cleaning small community gardens, pollinator gardens, curbside green spaces with native plants, art parks, small pocket parks, small playgrounds, and picnic areas.

KIB needs your help designing a green space for a community that has submitted an application packet for a $1,000 green space grant. We have provided you two application packets for green space. The application packet contains four parts: (1) Community Description, (2) Project Importance, (3) Space Vision, and (4) Maintenance Plan. A data table given to applicants explains each of the four parts. We have also provided you a green space materials cost sheet. The materials cost sheet lists materials and their cost associated with each application. Each green space design team member in your group is responsible for completing a specific job. We provided a description of team member roles and responsibilities.

<u>Here is what we need you to do:</u>

Your first goal: Read each of the four items in each application packet. Choose a community green space project to design.

Your second goal: Design a green space according to the details in the application packet. The design must include all of the elements of your chosen application packet. You will need to make a drawing to showcase your design.

Your third goal: Create a budget for all materials used in your design. Please include all of your calculations for the budget. For example. 4 large bags of soil at $4.28 each = $17.12 total.

Your fourth goal: Create a poster that shows:

1. A design model of your green space.
2. An explanation of why your design model fits the community's needs. For example, what did you read in the application packet that influenced your design? What are some things in your design that can be made differently? What limited your design? What other designs did you consider? Why did you not propose those designs?
3. Include your budget and all calculations in your poster.

Your green space design may become a model for designing future KIB green spaces.

Thank you.
Marie Clark, KIB Program Manager

Define the Problem

1. What is the setting of the client's problem?

2. What is the goal to achieve?

3. Explain your initial idea for a green space model.

4. List the steps (descriptions and procedures) you will use to make a good model.

5. What are the variables in your model?

6. How will you document your model?

Urban Green Spaces 2.0

Team Roles and Responsibilities

Team Roles	Team Member's Name	Responsibility
Project Manager		• Keep the team on track to complete the project on time • Check-in with team members to offer support • Keep detailed notes to write the explanation of your design
Project Designer		• Draft the project design according to the client's request • Work with the *Materials Manager* to determine project needs • Determine any project design materials
Materials Manager		• Work with the *Project Designer* to determine materials needed • Calculate the cost and number of materials needed • Pick up materials for the final poster
Communication Manager		• Communicate to your team how to present the final poster • Work with the *Project Manager* to write the explanation of your design • Organize your team to present the final poster

KIB Community Project Data Table

Item	Item Description
Community Description	The ***community description*** describes the condition of the community. Information includes the population size, neighborhood size, *tree cover data, crime rate, income rate, and the *walkability score. * means that you should see a note below for more information.
Project Importance	The ***project's importance*** includes the location of the community's green space. It also explains the importance of green space to the community. This section also describes how the project enhances the community. For example, some projects may rebuild a park to include a pollinator garden or a vegetable garden. In addition, some green spaces might increase sociability where community members can interact and get to know each other.
Space Vision	The ***space vision*** explains the design for the green space in the community. The space vision also describes how the community will use the green space and what type of equipment the community wants in the green space.
Maintenance Plan	The ***maintenance plan*** communicates how the community plans to maintain the green space once the project is complete.

*Tree cover data tells us the percentage of land with tree canopy coverage.

Why is tree cover data important? Sufficient tree canopy coverage has several positive impacts: improved air quality, decreased summer cooling costs, natural stormwater drainage, and aesthetic value.

*Walkability score tells us how walkable a neighborhood is based on the presence of sidewalks, intersections, and public transportation.

Why is the walkability score important? Walkability is important to residents' health and well-being and is also related to the desirability of areas for many demographic groups, particularly younger generations. It is also important to the inclusiveness of a community to persons with disabilities and to the ability to support storefront-type retail.

Urban Green Spaces 2.0

Green Space Materials Budget Sheet

Item	Quant	Price	Quant	x	Price	Total	Comments
Wood for garden beds (4 x 8)	4 planks a pack	5.52		x			
Soil	1 large bag	4.28		x			
Flower seeds	1 pack	1.58		x			
Tomato seeds	1 pack	2.73		x			
Cucumber seeds	1 pack	.58		x			
Carrot seeds	1 pack	2.49		x			
Garden tool set	1 set	16.51		x			
Water hose	1, 50 feet long	29.97		x			
Grass	1, 20-pound bag	26.66		x			
Mulch	1 large bag	3.33		x			
Shade tree (redwood)	1	29.98		x			
Park bench & table set	1 (fit 8 people)	75.00		x			
Swing Set	1 (fit 5 people)	0.00		x			Donation from Indianapolis
Merry-go-round	1 (fit 5 people)	0.00		x			Donation from Indianapolis
Outdoorcooking equipment	1 unit	40.00		x			
Picnic area shelter	1 unit (fit 50)	0.00		x			Donation from Indianapolis
Removal of debris	1 to 3 miles	200.00		x			
Gravel	1 to 3 miles	50.00		x			
Green space signage	1	75.00		x			
Volunteers	Indicate how many volunteers	0.00		x			
Maintenance	Explain your maintenance plan.			x			

BudgetTotals	**Total Amount Green Space Grant**	**Total Cost of Materials**	**Remaining Balance**

Rivoli Park Neighborhood Application

Community Description
Rivoli Park neighborhood in Indianapolis was once a vibrant community; the near east side in Indianapolis was drastically affected by the economic downfall in 2008. As a result, the near east side has experienced a rise in crimes and abandoned houses. As a result, this hard-working community faces financial instability and hopes that through the support of the KIB grant, they can transform a vacant lot into a park.

Project Importance
The park will create a green space for neighborhood socializing and for children to play and explore. This project will also create a green space for all community members to enjoy. The green space will help re-establish the neighborhood as a safe and friendly place for families and help rebuild a community. The new park will be the community's first and only park within a 10-minute walk for Rivoli Park residents.

Space Vision
The park is envisioned as a green space that will include tables and benches for socializing. In addition, the space will include playground equipment where children can play and where adults can come together to socialize. The green space will also serve the community as a site for neighborhood birthday parties, church cookouts, and a community meeting space.

Maintenance Plan
The community plans to organize a volunteer schedule where neighbors rotate mowing, pick up trash, and make sure the park equipment is working properly. In addition, Rivoli Park residents have agreed to donate $15.00 per year for maintenance costs.

Ransom Place Neighborhood Application

Community Description
This once-thriving community, the Ransom Place neighborhood, has undergone several hardships. Surrounded by Indiana University – Purdue University Indianapolis, the Ransom Place neighborhood has often been overlooked by the Indianapolis Parks Association. As a result, one of the two parks in this large neighborhood is no longer in safe working condition. This large family-oriented community hopes to rebuild the non-working park to make a safe green space for the community.

Project Importance
The green space will establish a safe and fun area in the community where Ransom Place neighbors can gather together to celebrate good times and work together to enhance the neighborhood. In addition, the new green space will increase neighborhood pride.

Space Vision
The community has voted to rebuild the non-working park. The community would like to see the park gain a new sign, playground equipment, tables, benches, and grass and mulch.

Maintenance Plan
The community organized a volunteer schedule where neighbors rotate mowing, picking up trash, and making sure the park equipment is working properly. In addition, ransom Place residents have agreed to donate $5.00 a year for maintenance costs.

Urban Green Spaces 2.0

Common Core State Standards Potentially Addressed

Geometry K-4
CCSS.MATH.CONTENT.4.G.A.1
Draw points, lines, line segments, rays, angles (right, acute, obtuse), and perpendicular and parallel lines. Identify these in two-dimensional figures.
Math Standards for Operations & Algebraic Thinking K-5Number and Operations in Base Ten
Understand the place value system.
Perform operations with multi-digit whole numbers and with decimals to hundredths.
CCSS.MATH.CONTENT.5.NBT.B.7
Add, subtract, multiply, and divide decimals to hundredths, using concrete models or drawings and strategies based on place value properties of operations, and/or the relationship between addition and subtraction; relate the strategy to a written method and explain the reasoning used.
Apply and extend previous understandings of multiplicationand division.
CCSS.MATH.CONTENT.5.NF.B.6
Solve real-world problems involving multiplication of fractions andmixed numbers, e.g., by using visual fraction models or equations to represent the problem.
Measurement and Data
Convert like measurement units within a given measurement system.
CCSS.MATH.CONTENT.5.MD.A.1
Convert among different-sized standard measurement units within agiven measurement system (e.g., convert 5 cm to 0.05 m), and use these conversions in solving multi-step, real-world problems.
Reading Standards for Literature K–5Key Ideas and Details
CCSS.ELA-LITERACY.RL.5.1
Quote accurately from a text when explaining what the text says explicitly and when drawing inferences from the text.
Range of Reading and Level of Text Complexity
CCSS.ELA-LITERACY.RL.5.10
By the end of the year, read and comprehend literature, including stories, dramas, and poetry, at the high end of the grades 4–5 text complexity band independently and proficiently.
Reading Standards for Informational Text K–5 Key Ideas and Details
CCSS.ELA-LITERACY.RI.5.1
Quote accurately from a text when explaining what the text says explicitly and when drawing inferences from the text.
CCSS.ELA-LITERACY.RI.5.2
Determine two or more main ideas of a text and explain how they are supported by key details; summarize the text.
CCSS.ELA-LITERACY.RI.5.3
Explain the relationships or interactions between two or more individuals, events, ideas, or concepts in a historical, scientific, or technical text based on specific information in the text.
Craft and Structure
CCSS.ELA-LITERACY.RI.5.4
Determine the meaning of general academic and domain-specific words and phrases in a text relevant to a *grade 5 topic or subject area*.
Integration of Knowledge and Ideas
CCSS.ELA-LITERACY.RI.5.7
Draw on information from multiple print or digital sources, demonstrating the ability to locate an answer to a question quickly or to solve a problem efficiently.
Range of Reading and Level of Text Complexity
CCSS.ELA-LITERACY.RI.5.10
By the end of the year, read and comprehend informational texts, including history/social studies, science, and technical texts, at the high end of the grades 4–5 text complexity band independently and proficiently.
Writing Standards K–5 Text Types and Purposes
CCSS.ELA-LITERACY.W.5.2
Write informative/explanatory texts to examine a topic and convey ideas and information clearly.
CCSS.ELA-LITERACY.W.5.2.A
Introduce a topic clearly, provide a general observationand focus, and group related information logically; include formatting (e.g., headings), illustrations, and multimedia when useful to aiding comprehension.
CCSS.ELA-LITERACY.W.5.2.B
Develop the topic with facts, definitions, concrete details, quotations, or other information and examplesrelated to the topic.
CCSS.ELA-LITERACY.W.5.2.C
Link ideas within and across categories of informationusing words, phrases, and clauses (e.g., *in contrast*, *especially*).
CCSS.ELA-LITERACY.W.5.2.D
Use precise language and domain-specific vocabularyto inform about or explain the topic.
CCSS.ELA-LITERACY.W.5.2.E
Provide a concluding statement or section related to theinformation or explanation presented.
Production and Distribution of Writing
CCSS.ELA-LITERACY.W.5.4
Produce clear and coherent writing in which the development and organization are appropriate to task, purpose, and audience. (Grade-specific expectations for writing types are defined in standards 1–3 above.)
Speaking and Listening Standards K–5Comprehension and Collaboration CCSS.ELA-LITERACY.SL.5.1
Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on *grade 5 topics and texts*, building on others' ideas and expressing their own clearly.
CCSS.ELA-LITERACY.SL.5.1.A
Come to discussions prepared, having read or studied required material; explicitly draw on that preparation andother information known about the topic to explore ideasunder discussion.
CCSS.ELA-LITERACY.SL.5.1.B
Follow agreed-upon rules for discussions and carry outassigned roles.
CCSS.ELA-LITERACY.SL.5.1.C
Pose and respond to specific questions by making comments that contribute to the discussion and elaborateon the remarks of others.
CCSS.ELA-LITERACY.SL.5.1.D
Review the key ideas expressed and draw conclusionsin light of information and knowledge gained from the discussions.
CCSS.ELA-LITERACY.SL.5.2
Summarize a written text read aloud or information presented in diverse media and formats, including visually, quantitatively, and orally.

APPENDIX J. HEALTHY FOOD CHOICES 2.0

Healthy Food Choices 2.0

Cover Page

Topic
Public health in the context of nutrition-related to food choices

Key Questions
How do consumers use the Nutrition Facts Label information to make healthy food choices?

Goals
Students will:

1. Solve real-world problems using mathematical models
2. Cycle through the iterative engineering design cycle of express-test-revise
3. Engage in statistical thinking while working collaboratively
4. Make decisions about the effectiveness of a solution
5. Prepare written and verbal reports of a viable solution

Guiding Documents
This MEA is aligned with selected Standards for Mathematical Practices (SMPs) and Standards of Mathematics Content (SMC). However, as implementation strategies and student solutions may vary, not all standardsmay apply. Please see Appendix A for a complete list of Common Core State Standards (CCSS) that may nutrition-related.

Team Formation

- Essential elements for compelling cooperative learning experiences, the elimination of nonparticipation, andproviding accountability for students to work effectively in completing tasks as a team include:
- Creating small teams of 4 students for the duration of the MEA. Advise students that they cannot changeteams
- Establishing individual accountability by assessing students both individually and as a team
- Building interdependence by assigning team roles and interdependent tasks; The team can only completethe MEA if all team members perform their individual tasks

Recommended Supplies for all Modeling-Eliciting Activities
It is recommended to have all supplies in a central location in the room. In addition, it is recommended to let the students know that they are available, but not to encourage them to use specific supplies.

1. TI-15 Explorer Elementary or equivalent calculators
2. Standard 12-inch rulers (metric or standard units; rulers should be consistent across classroom usage)
3. Colored pencils
4. Number 2 pencils
5. Wide ruled composition notebooks or loose-leaf paper

Healthy Food Choices 2.0

Team Roles and Responsibilities

Team Roles	Team Member's Name	Responsibility
Project Manager		• Work with the *Communication Manager* to help keep your teamon track to complete the project on time • Keep detailed notes to help your team develop the finalpresentation
Project Designer		• Work with the *Materials Manager* to determine project materialsor resources needed • Help your team develop a procedure or set of guidelines for theproject
Materials Manager		• Work with the *Project Designer* to determine project materials orresources needed • Help your team calculate a procedure or write a set of guidelines
Communication Manager		• Work with the *Project Manager* to help your team develop thefinal presentation • Organize your team to present the final presentation

Reading the Nutrition Facts Label Can Help People Make Healthy Food Choices

The Nutrition Facts Label found on packaged foods and drinks contains important information about the food you eat. There are four basic parts of the Nutrition Facts Label. **Part one** tells you the serving size. **Part two** lists the number of calories in one serving. **Part three** lists the amount of **fat**, **carbohydrates (carbs)**, and **protein** in each serving. **Part four** lists the number of **vitamins** and **minerals** in each serving, like vitamin D and iron.

The body needs the right amount of nutrients (fats, carbs, and protein), vitamins, and minerals to function and grow properly. **Calories** are the amount of energy a food contains. **Fat, carbs, and protein** are substances that help our bodies to grow. **Fat** provides our bodies with energy from foods like nuts and fish. **Carbs** provide our bodies with the primary source of energy from foods like pasta and fruit. **Protein** helps make muscle strength, can also be used for energy, and can be found in foods like chicken and beans. **Vitamins** are substances found in many foods that help our bodies develop and function. **Minerals** are natural substances like iron and calciumthat help our bodies grow and develop. Minerals may be found in soil.

Many factors influence food choices. As a result, choosing healthy foodoptions can be challenging.

A few ways to make healthier food choices are:

1. Avoid sugary drinks.
2. Limit the number of sauces that contain lots of sugar, like mayonnaise and ketchup.
3. Eat plenty of fruits and vegetables.

Healthy Food Choices 2.0

Guided Discussion Questions

Do you eat certain foods because they are available?

A. What are other factors that help you decide what to eat?
B. Do you eat certain foods because they taste good?
C. Do you eat certain foods because they are healthy?
D. Do you eat what your family eats?

Review the bolded terms in the news article to ensure you understand the terms. You can also use the chart provided below.

Nutrition Facts Definitions

1. The block on foods that list nutrition facts
2. The amount of energy a food contains
3. The substances in food that help bodies to grow
4. Natural substances that are found in soil
5. The substances that are found in many foods, which help ourbodies develop and function

Nutrition Facts Terms	
Calories	
Minerals	
Nutrients	
Nutrition Facts Label	
Vitamins	

Do you think knowing how many calories you are eating per serving will help you eat fewer cookies? Why or why not?

Answer questions A-D using the Nutrition Facts Label to the right.

A. How many servings are there per container?
B. How many calories are there per serving?
C. How many calories are in the entire container?
D. How many grams of total sugar is in the entire container?

Nutrition Facts

24 servings per container
Serving size **1 cookie (30g)**

Amount per serving
Calories **160**

	% Daily Value*
Total Fat 8g	**10%**
Saturated Fat 5g	**24%**
Trans Fat 0g	
Cholesterol 30mg	**9%**
Sodium 75mg	**3%**
Total Carbohydrate 20g	**7%**
Dietary Fiber 0g	**1%**
Total Sugars 9g	
Includes 9g Added Sugars	**19%**
Protein 2g	**4%**
Vitamin D 0mcg	0%
Calcium 20mg	2%
Iron 0mg	4%
Potassium 20mg	0%

* The % Daily Value (DV) tells you how much a nutrient in a serving of food contributes to a daily diet. 2,000 calories a day is used for general nutrition advice.

Healthy Food Choices 2.0

Problem Statement

To: Students of Cold Spring Elementary
From: Karen Robinson, Director of Nutrition Education at Food 4 Us
Subject: Creating Healthy Eating Habits

My name is Karen Robinson from Food 4 Us. I help people make healthy food choices by using the information on theNutrition Facts Label. Many people do not know the appropriate amount of fat, carbs, protein, and calories they shouldeat each day. Knowing the appropriate amount of fat, carbs, protein, and calories to eat each day can help you make healthy food choices. The appropriate amount of fat, carbs, protein, and calories a person should eat each day depends on a person's age and level of physical activity. Food 4 Us is developing a food app to help individuals make healthierfood choices.

I need your help to develop a procedure or set of guidelines that determine an appropriate amount of fat, carbs, protein,and calories that a person should eat each day. Because people need a variety of foods in their diets, your model shouldinclude choices that include different foods. The data tables attached to this letter will help your team develop a procedure or set of guidelines. Each team member in your group is responsible for completing a specific job.

Here is what I need your team to do:
Create a final presentation that describes how your team completes each of the four goals listed below.

Your first goal: Select a level of activity for an individual type. The Level of Physical Activity table can help you select an individual type. Choose an age group.
Your second goal: Decide what the individual might eat in a single day for breakfast, lunch, and dinner. Calculate the amount of fat, carbs, protein, and calories based upon your food selections. The data charts will help you decide what the individual might eat and the amount of fat, carbs, protein, and calories for each food item. Remember that your food choices should lead to staying in the appropriate range of calories.
Your third goal: Construct a procedure or set of guidelines that would help this type of individual make healthy foodchoices and stay in the appropriate range of daily calories. Explain how the amount of fat, carbs, and protein may be different from the daily recommended amounts of fat, carbs, protein, and calories in the data chart.
Your fourth goal: Select a different type of individual. Test your procedure or set of guidelines you created with a different type of individual. Explain how your group tested your procedure or set of guidelines. Explain how your procedure or set of guidelines will need to change for a different individual? What are some limitations to your procedure?

You should use math symbols, graphs, tables, words, equations, and pictures to explain and justify your procedure orset of guidelines. Take notes as you develop your procedure or set of guidelines because different ideas (right or wrong) are valuable. Our notes remind us of what works and what does not work.

Food 4 Us may use your procedure or set of guidelines to help others make healthier food choices.

Sincerely,

Karen Robinson, Director of Nutrition Education at Food 4 Us

Healthy Food Choices 2.0

Define the Problem

1. What is the setting of the client's problem?

2. What is the goal to achieve?

3. Explain your initial idea for a food app model.

4. List the steps (descriptions and procedures) you will use to develop a good model.

5. What are the variables in your model?

6. How will you document your model?

Levels of Physical Activity Data Chart

The number of calories you need each day depends on the following two facts.

1. Your age
2. Your typical activity levels

The table below defines each level of activity.

Not Active	Somewhat Active	Very Active
Not much ENERGY used. Does only light activity. For example, cooking or walking to the mailbox, cleaning the house, or playing video games, does only light activity that is needed for daily life.	Some ENERGY used. Does some physical activity. For example, walking fast for 1½ to 3 miles (about 30-40 minutes) each day, as well as light activity needed for daily life.	A lot of ENERGY used. Does physical activity. For example, walking fast for more than 3 miles each day (more than 40 minutes), running, playing soccer, or playing basketball, as well as light activity needed for daily life.

Daily Recommendations for Calories and Nutrients Chart

The number of calories needed differs by age, gender, and the level of regular physical activity.

- For children, more calories are needed at older ages.
- For adults, fewer calories are needed at older ages.

The table lists the daily recommended calories per age group and activity level.

Age	Not Active	Somewhat Active	Very Active
4-8 years	1,200 - 1,400	1,400 - 1,600	1,600 - 1,800
9-13 years	1,600 - 1,800	1,800 - 2,000	2,000 - 2,200
14 years and older	2,200 - 2,400	2,400 - 2,600	2,600 - 2,800

The table below lists the daily recommended grams of protein, carbs, and fat per age group and activity level

	Age	Protein	Carbs	Fat
Not Active	4-8 years	161-171 g	106-116 g	40-50 g
Somewhat Active	9-13 years	201-211 g	136-146 g	53-63 g
Very Active	14 years and older	261-271 g	181-191 g	73-83 g

Healthy Food Choices 2.0

Food Nutrition Facts Chart

FRUIT	CALORIES	FATS (g)	CARBS (g)	PROTEIN (g)
Apple, 1 med	80	0	22	0
Avocado, ½ med	50	4.5	3	1
Banana, 1 med	110	0	30	1
Blueberries, 1 c	83	0.5	21.0	1.1
Cantaloupe, ¼ med	50	0	12	1
Grapefruit, ¼ med	60	0	15	1
Grapes, ¾ c	90	0	23	0
Kiwifruit, 2 med	90	1	20	1
Lemon, 1 med	15	0	5	0
Lime, 1 med	20	0	7	0
Nectarine, 1 med	60	0.5	15	1
Orange, 1 med	80	0	19	1
Papaya, 1 c	55	0.2	11.2	0.9
Peach, 1 med	60	0.5	15	1
Pineapple, 2 slices	50	0	13	9
Plums, 1 med	37.5	0	9.5	0.5
Strawberries, 8 med	50	0	11	1
Cherries, 21 cherries	100	0	26	9
Tangerine, 1 med	50	0	13	1
Watermelon, 2 cs	80	0	21	1
VEGETABLES	**CALORIES**	**FATS(g)**	**CARBS(g)**	**PROTEIN(g)**
Asparagus, 5 spears	20	0	4	2
Beets, ½ c	29	0	6.5	1
Broccoli, 1 c	45	0.5	8	4
Brussels sprouts, 1 c	38	0	8	3
Carrots, 1 c	30	0	7	1
Cauliflower, 1 c	20	0.2	3.9	1.9
Celery, 1 c	42	0.3	9.1	1.5
Cucumber	16	0	2	0.5
Green (snap) beans, 1 c	131	0	7	2
Green Cabbage, ½ c	25	0	5	1
Iceberg Lettuce, ½ c	20	0	4	2
Kale, 1 c	8	0.1	1.4	0.7
Onion, 1 c	40	0	10	1
Pepper (bell), 1 med	25	0	6	1
Potato (white) 1 med	128	0.2	29	3.5
Potato (sweet) 1 med	115	0.2	27	2.1
Spinach, 1 c	41	0.5	6.8	5.3
Squash (summer), 1 c	74	5.4	6.1	2.6
Tomato, 1 med	22	0.3	4.8	1.1
Zucchini, 1 med	33	0.6	6	4.9

Healthy Food Choices 2.0

Food Nutrition Facts Chart

BEANS & GRAINS	CALORIES	FATS(g)	CARBS(g)	PROTEIN(g)
Beans (black), 1 c	227	0.9	41	15
Beans (white), 1 c	249	0.6	45	17
Beans (chickpeas), 1 c	269	4.2	45	15
Beans (lentils), 1 c	226	0.8	39	18
Bread (wheat), 2 slices	154	1.9	28	6.2
Bread (white), 2 slices	198	2.4	36	6.6
Bread (pita), 1	168	1.1	36	6.3
Crackers (wheat), 4	38.4	1.4	6	0.6
Crackers (white), 4	80	4.4	10	1.1
Cookies, 2 med	296	14.8	40	3
Corn, 1 ear	99	1.5	22	3.5
Cornbread, 1 piece	173	4.6	28	4.4
Noodles (spaghetti), 1 c	196	1.2	38	7.2
Oatmeal, 1 c	166	3.6	28	5.9
Popcorn (plain), 3 c	90	1	19	3
Popcorn (buttered), 3 c	234	15.81	21.81	2.88
Pretzels, ½ c	436	3.3	92	11.2
Rice (brown), ½ c	109	0.8	23	2.3
Rice (white), ½ c	102.5	0.2	22.5	2.1
Tortilla (flour), 1 med	234	5.1	40	6.3
Waffle, 1	218	11	25	5.9
MEAT & FISH	**CALORIES**	**FATS(g)**	**CARBS(g)**	**PROTEIN(g)**
Chicken, 4 oz	249	14.7	0	26.7
Hamburger, 4 oz	262	16	0	28
Steak, 4 oz	230	22	0	19
Pork chop, 4 oz	289	17	0	29
Turkey , 4 oz	214	8.4	0	32
Fish, 4 oz	109	2.3	0	22
Salmon, 4 oz	234	14	0	25
Shrimp, 4 oz	80	0.7	0	17
Tuna, 4 oz	148	0.7	0	33
NUTS & SEEDS	**CALORIES**	**FATS(g)**	**CRABS(g)**	**PROTEIN(g)**
Almonds, 23	163	14	6	6
Peanuts, 23	161	14	4.6	7
Pumpkin seeds, 23	126	5	15	5
Sunflower seeds, 23	166	15	6	6
Walnuts, 14	185	18	3.9	4.3
DAIRY/NON-DAIRY	**CALORIES**	**FATS(g)**	**CRABS(g)**	**PROTEIN(g)**
Cheese, 1 slice	113	9.3	0.9	6.4
Egg, 1 whole	50	4.8	0.4	6.3
Ice cream, 1 c	273	15	31	4.6
Milk (whole), 1 c	125	4.7	12	8.5
Milk (soy), 1 c	100	4	8	7
Yogurt, 3 oz	53	1.3	6	4.5

Healthy Food Choices 2.0

Healthy Meal Planner

Meal	Food/Drink	Serving Size	# of Servings	Fat	Carbs	Sugars	Protein	Calories
BREAKFAST								
DAILY TOTALS								

Meal	Food/Drink	Serving Size	# of Servings	Fat	Carbs	Sugars	Protein	Calories
LUNCH								
DAILY TOTALS								

Meal	Food/Drink	Serving Size	# of Servings	Fat	Carbs	Sugars	Protein	Calories
DINNER								
DAILY TOTALS								

Healthy Food Choices 2.0

Common Core State Standards Potentially Addressed

Geometry K-4
CCSS.MATH.CONTENT.4.G.A.1
Draw points, lines, line segments, rays, angles (right, acute, obtuse), and perpendicular and parallel lines. Identify these in two-dimensional figures.
Math Standards for Operations & Algebraic Thinking K-5Number and Operations in Base Ten
Understand the place value system.
Perform operations with multi-digit whole numbers and with decimals to hundredths.
CCSS.MATH.CONTENT.5.NBT.B.7
Add, subtract, multiply, and divide decimals to hundredths, using concrete models or drawings and strategies based on place value properties of operations, and/or the relationship between addition and subtraction; relate the strategy to a written method and explain the reasoning used.
Apply and extend previous understandings of multiplicationand division.
CCSS.MATH.CONTENT.5.NF.B.6
Solve real-world problems involving multiplication of fractions andmixed numbers, e.g., by using visual fraction models or equations to represent the problem.
Measurement and Data
Convert like measurement units within a given measurement system.
CCSS.MATH.CONTENT.5.MD.A.1
Convert among different-sized standard measurement units within agiven measurement system (e.g., convert 5 cm to 0.05 m), and use these conversions in solving multi-step, real-world problems.
Reading Standards for Literature K–5Key Ideas and Details
CCSS.ELA-LITERACY.RL.5.1
Quote accurately from a text when explaining what the text says explicitly and when drawing inferences from the text.
Range of Reading and Level of Text Complexity
CCSS.ELA-LITERACY.RL.5.10
By the end of the year, read and comprehend literature, including stories, dramas, and poetry, at the high end of the grades 4–5 text complexity band independently and proficiently.
Reading Standards for Informational Text K–5 Key Ideas and Details
CCSS.ELA-LITERACY.RI.5.1
Quote accurately from a text when explaining what the text says explicitly and when drawing inferences from the text.
CCSS.ELA-LITERACY.RI.5.2
Determine two or more main ideas of a text and explain how they are supported by key details; summarize the text.
CCSS.ELA-LITERACY.RI.5.3
Explain the relationships or interactions between two or more individuals, events, ideas, or concepts in a historical, scientific, or technical text based on specific information in the text.
Craft and Structure
CCSS.ELA-LITERACY.RI.5.4
Determine the meaning of general academic and domain-specific words and phrases in a text relevant to a *grade 5 topic or subject area*.
Integration of Knowledge and Ideas
CCSS.ELA-LITERACY.RI.5.7
Draw on information from multiple print or digital sources, demonstrating the ability to locate an answer to a question quickly or to solve a problem efficiently.
Range of Reading and Level of Text Complexity
CCSS.ELA-LITERACY.RI.5.10
By the end of the year, read and comprehend informational texts, including history/social studies, science, and technical texts, at the high end of the grades 4–5 text complexity band independently and proficiently.
Writing Standards K–5 Text Types and Purposes
CCSS.ELA-LITERACY.W.5.2
Write informative/explanatory texts to examine a topic and convey ideas and information clearly.
CCSS.ELA-LITERACY.W.5.2.A
Introduce a topic clearly, provide a general observationand focus, and group related information logically; include formatting (e.g., headings), illustrations, and multimedia when useful to aiding comprehension.
CCSS.ELA-LITERACY.W.5.2.B
Develop the topic with facts, definitions, concrete details, quotations, or other information and examplesrelated to the topic.
CCSS.ELA-LITERACY.W.5.2.C
Link ideas within and across categories of informationusing words, phrases, and clauses (e.g., *in contrast*, *especially*).
CCSS.ELA-LITERACY.W.5.2.D
Use precise language and domain-specific vocabularyto inform about or explain the topic.
CCSS.ELA-LITERACY.W.5.2.E
Provide a concluding statement or section related to theinformation or explanation presented.
Production and Distribution of Writing
CCSS.ELA-LITERACY.W.5.4
Produce clear and coherent writing in which the development and organization are appropriate to task, purpose, and audience. (Grade-specific expectations for writing types are defined in standards 1–3 above.)
Speaking and Listening Standards K–5Comprehension and Collaboration CCSS.ELA-LITERACY.SL.5.1
Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on *grade 5 topics and texts*, building on others' ideas and expressing their own clearly.
CCSS.ELA-LITERACY.SL.5.1.A
Come to discussions prepared, having read or studied required material; explicitly draw on that preparation andother information known about the topic to explore ideasunder discussion.
CCSS.ELA-LITERACY.SL.5.1.B
Follow agreed-upon rules for discussions and carry outassigned roles.
CCSS.ELA-LITERACY.SL.5.1.C
Pose and respond to specific questions by making comments that contribute to the discussion and elaborateon the remarks of others.
CCSS.ELA-LITERACY.SL.5.1.D
Review the key ideas expressed and draw conclusionsin light of information and knowledge gained from the discussions.
CCSS.ELA-LITERACY.SL.5.2
Summarize a written text read aloud or information presented in diverse media and formats, including visually, quantitatively, and orally.

APPENDIX K. RENEWABLE ENERGY 2.0

Renewable Energy 2.0

Cover Page

Model-Eliciting Activity (MEA) Topic
Renewable Energy

Key Questions
What are some ways to increase access to renewable energy?

Goals
Students will:

1. Solve real-world problems using mathematical models
2. Cycle through the iterative engineering design cycle of express-test-revise
3. Engage in statistical thinking while working collaboratively
4. Make decisions about the effectiveness of a solution
5. Prepare written and verbal reports of a viable solution

Guiding Documents
This MEA is aligned with selected Standards for Mathematical Practices (SMPs) and Standards of Mathematics Content (SMC). However, as implementation strategies and student solutions may vary, not all standardsmay apply. Please see Appendix A for a complete list of Common Core State Standards (CCSS) that may apply.

Team Formation
Essential elements for compelling cooperative learning experiences, the elimination of nonparticipation, andproviding accountability for students to work effectively in completing tasks as a team include:

- Creating small teams of 4 students for the duration of the MEA. Advise students that they cannot changeteams
- Establishing individual accountability by assessing students both individually and as a team
- Building interdependence by assigning team roles and interdependent tasks. The team can only completethe MEA if all team members perform their individual tasks

Recommended Supplies for all Modeling-Eliciting Activities
It is recommended to have all supplies in a central location in the room. In addition, it is recommended to let the studentsknow that they are available, but not to encourage them to use specific supplies.

1. TI-15 Explorer Elementary or equivalent calculators
2. Standard 12-inch rulers (metric or standard units; rulers should be consistent across classroom usage)
3. Colored pencils
4. Number 2 pencils
5. Wide ruled composition notebooks or loose-leaf paper

Renewable Energy 2.0

Team Roles and Responsibilities

Team Roles	Team Member's Name	Responsibility
Project Manager		• Work with the *Communication Manager* to help keep your team ontrack to complete the project on time • Keep detailed notes to help your team develop the final presentation
Project Designer		• Work with the *Materials Manager* to determine project materials orresources needed • Help your team develop a procedure or set of guidelines for theproject
Materials Manager		• Work with the *Project Designer* to determine project materials orresources needed • Help your team calculate a procedure or write a set of guidelines
Communication Manager		• Work with the *Project Manager* to help your team develop the finalpresentation • Organize your team to present the final presentation

Renewable Energy 2.0

Advanced Organizer / News Article

What is renewable energy? Renewable energy ismade from natural sources. The word renewable means that the energy source will always be available. Two sources of renewable energy are the sun and wind energy. The energy that comes from the sun is called solar energy. The word solar means sun. Solar energy can be used to heat homes, buildings, and water. For example, you might have experienced solar energy when sitting in a car after the sun heated the inside of the car on a hot sunny day. Wind energy is made when air blows through wind turbines. The wind must blow at 15 miles per hour (MPH) or faster to produce wind energy.

There are many benefits to affordable renewable energy that comes from natural sources like the sun or wind. For example, the state of California's Energy for All Program has provided over 13 thousand no-cost solar systems to homeowners that qualified as low income. Benefits include putting money back into families' pockets, increased housing affordability, lower energy cost, and over 50 thousand job training opportunities for residents.

Many cities and states are offering renewable energy programs for all households. For example, Indianapolis's city offers large tax credits to homeowners who install solar panels on their homes. A federal tax credit is money that a person can subtract from the amount of taxes they owe. The 2019 Solar Investment Tax Credit (ITC) is worth 26% of your total system. So, for example, if you pay $10,000 to install your solar system, you would be owed a $2,600 tax credit. In addition, the 51st State Solar Co-op program in Washington, DC, seeks to provide solar electricity to 100,000 low-income homeowners and reduce their energy bills by 50% by 2023.

Some people may not own their homes, or they may live in an apartment. This makes it difficult to control the roof or land space needed to install a renewable energy system like solar panels. Many local and community programs help households take advantage of renewable energy. For example, a renewable energy project installed solar panels on a local church in Maryland. Another example is in rural Iowa, where 200 people worked together to install seven wind turbines in their community.

Learn more about how community renewable energy programs work at
https://www.citizensutilityboard.org/community-solar-illinois/

Renewable Energy 2.0

Guided Discussion Questions

Several communities across America participated in the *Solar in Your Community Challenge*. Learn more about the community programs that participated in the challenge at (https://www.energy.gov/eere/solar/solar- your-community-challenge).

- Can you think of ways your community can work together to create a communityrenewable energy program?
- How might people get organized to establish a renewable energy program?

The data chart below indicates the states with an active low-income solar program and those that do not have an active low-income solar program.

For Example:

- A family who owns their home in Illinois has joined a low-income solar program. Discuss with a partner the benefits of joining a statewide low-income solar program for the family. Consider benefits to our planet.

More data charts can be found at https://www.solarpowerrocks.com/in

Renewable Energy 2.0

Problem Statement

To: Students of Cold Spring Elementary
From: Karen Smith, Director of Solar Systems for Homeowners
Subject: Helping Homeowners Save with Solar Energy Systems

We help homeowners figure out how much money they can save if they install a solar energy system in their homes. We have a new program that offers homeowners a no-interest loan for installing solar energy panels. The homeowner must agree to pay back the loan within 10-years. Under our program, homeowners could pay less money per year for electricity. We need your help to communicate information to homeowners about our loan program.

Here is what we need you to do:

Develop a presentation (Google Slide, PowerPoint, videocast, or other) about our loan program. Your team's presentation should address goals 1 through 3 listed below. We provide information to help develop your presentation. We also provide a description of team member roles andresponsibilities.

Goal 1. Determine utility costs per month by completing Table 1. Then compare the utilitycost with the cost of solar panels in Table 2. Table 3 is an estimate of energy cost per month for each type of home. Determine how much money homeowners would save by installing solar panels.

Goal 2. Determine how much money homeowners of different home types might save over ten years.The loan is paid off after 10-years. Thus, the cost for someone with solar panels on year 11 is $0.

Goal 3. Describe your procedure for goals #1 and #2. Your written description should communicate how to calculate the amount of money saved by installing solar panels eachmonth, each year, and after ten years.

You should use math symbols, graphs, tables, words, equations, and pictures to explain and give good reasons why your procedure works. Take notes along the way because different ideas (correct or incorrect) remind us of what works and what does not work.

Thank you,

Karen Smith
Director of Solar Systems for Homeowners

Define the Problems

1. What is the setting of the client's problem?

2. What is the goal to achieve?

3. Explain your initial idea for estimating the cost of solar systems.

4. List the steps (descriptions and procedures) you will use to develop a good model.

5. How will you document your model?

Renewable Energy 2.0

Information to Help Develop Your Presentation

Energy usage is expressed in kilowatt-hour (kWh), which describes how much energy is used. The utility companycharges $0.13 for each kWh used in a month.

Table 1 can be used to estimate the energy that a household might use. The minimum amount of energy supplied by solar panels for an apartment, townhouse, or home is given in Table 2. The monthly loan cost is also shown in Table 2. Table 3 gives an example of a typical household energy cost per month. Your numbers may be different.

The range of values (minimum-maximum) for the lightbulbs, television, and refrigerator is for typical apartments, townhouses, and single-family homes. Choose a value within each range that you think is appropriate, and be prepared to justify why you made that choice. Note: A month can be estimated as being 30 days.

Table 1: *Household energy use for various items. Note your team must calculate kWh for items 1-3.*

	Household Appliance	Kilowatt (kW)	Number of Items	Hours Per Day	kWh Per Day	kWh Per Month	Utility cost Per Month
1	**Light Bulb**	0.04 - 0.12	7-10	6-12			
2	**Television**	0.05 - 0.2	1-3	0-8			
3	**Refrigerator**	0.1 - 0.2	1	24			
4	**Microwave**	1.2	1	0.5	0.6	18	2.34
5	**Dishwater**	1.5	1	0.5	0.75	22.5	2.93
6	**Ceiling Fan**	0.1	2	0	0	0	0
7	**Washer/Dryer**	5	1	0.2	1	30	3.90
8	**Computer**	0.06	3	6	1.08	32.40	4.21
9	**Electric Oven**	2.25	1	1	2.25	67.50	8.78
10a	**Apartment Heater**	0.9	1	24	21.6	648	84.24
10b	**Townhouse Heater**	1.2	1	24	28.8	864	112.32
10c	**House Heater**	1.6	1	24	38.4	1152	149.76
11a	**Apartment Air Conditioner**	0.4	1	24	9.60	288	37.44
11b	**Townhouse Air Conditioner**	0.6	1	24	14.40	432	56.16
11c	**House Air Conditioner**	0.8	1	24	19.20	576	74.88

Note. For 10a - 11c, heating and AC are different between the type of homes. If the heater is on, then the AC is off, and vice versa.

Table 2: Minimum amount of energy supplied by solar panels, and their loan costs

Home Type	Minimum energy per month supplied by solar panels	Cost of the loan per month for solar panel installation
Apartment	2000 kWh/month	$100
Townhouse	2500 kWh/month	$125
Single-Family Home	3500 kWh/month	$150

Note. The loan will be paid off in 10 years (120 months).

Table 3: Typical household energy cost per month during a 12-month period

Home Type	Average energy (kWh) per month	Average utility cost per month
Apartment	1052	$136.76
Townhouse	1205	$156.65
Single-Family Home	1421	$184.73

Common Core State Standards Potentially Addressed

Geometry K-4
CCSS.MATH.CONTENT.4.G.A.1
Draw points, lines, line segments, rays, angles (right, acute, obtuse), and perpendicular and parallel lines. Identify these in two-dimensional figures.
Math Standards for Operations & Algebraic Thinking K-5Number and Operations in Base Ten
Understand the place value system.
Perform operations with multi-digit whole numbers and with decimals to hundredths.
CCSS.MATH.CONTENT.5.NBT.B.7
Add, subtract, multiply, and divide decimals to hundredths, using concrete models or drawings and strategies based on place value properties of operations, and/or the relationship between addition and subtraction; relate the strategy to a written method and explain the reasoning used.
Apply and extend previous understandings of multiplicationand division.
CCSS.MATH.CONTENT.5.NF.B.6
Solve real-world problems involving multiplication of fractions andmixed numbers, e.g., by using visual fraction models or equations to represent the problem.
Measurement and Data
Convert like measurement units within a given measurement system.
CCSS.MATH.CONTENT.5.MD.A.1
Convert among different-sized standard measurement units within agiven measurement system (e.g., convert 5 cm to 0.05 m), and use these conversions in solving multi-step, real-world problems.
Reading Standards for Literature K–5Key Ideas and Details
CCSS.ELA-LITERACY.RL.5.1
Quote accurately from a text when explaining what the text says explicitly and when drawing inferences from the text.
Range of Reading and Level of Text Complexity
CCSS.ELA-LITERACY.RL.5.10
By the end of the year, read and comprehend literature, including stories, dramas, and poetry, at the high end of the grades 4–5 text complexity band independently and proficiently.
Reading Standards for Informational Text K–5 Key Ideas and Details
CCSS.ELA-LITERACY.RI.5.1
Quote accurately from a text when explaining what the text says explicitly and when drawing inferences from the text.
CCSS.ELA-LITERACY.RI.5.2
Determine two or more main ideas of a text and explain how they are supported by key details; summarize the text.
CCSS.ELA-LITERACY.RI.5.3
Explain the relationships or interactions between two or more individuals, events, ideas, or concepts in a historical, scientific, or technical text based on specific information in the text.
Craft and Structure
CCSS.ELA-LITERACY.RI.5.4
Determine the meaning of general academic and domain-specific words and phrases in a text relevant to a *grade 5 topic or subject area*.
Integration of Knowledge and Ideas
CCSS.ELA-LITERACY.RI.5.7
Draw on information from multiple print or digital sources, demonstrating the ability to locate an answer to a question quickly or to solve a problem efficiently.
Range of Reading and Level of Text Complexity
CCSS.ELA-LITERACY.RI.5.10
By the end of the year, read and comprehend informational texts, including history/social studies, science, and technical texts, at the high end of the grades 4–5 text complexity band independently and proficiently.
Writing Standards K–5 Text Types and Purposes
CCSS.ELA-LITERACY.W.5.2
Write informative/explanatory texts to examine a topic and convey ideas and information clearly.
CCSS.ELA-LITERACY.W.5.2.A
Introduce a topic clearly, provide a general observationand focus, and group related information logically; include formatting (e.g., headings), illustrations, and multimedia when useful to aiding comprehension.
CCSS.ELA-LITERACY.W.5.2.B
Develop the topic with facts, definitions, concrete details, quotations, or other information and examplesrelated to the topic.
CCSS.ELA-LITERACY.W.5.2.C
Link ideas within and across categories of informationusing words, phrases, and clauses (e.g., *in contrast*, *especially*).
CCSS.ELA-LITERACY.W.5.2.D
Use precise language and domain-specific vocabularyto inform about or explain the topic.
CCSS.ELA-LITERACY.W.5.2.E
Provide a concluding statement or section related to theinformation or explanation presented.
Production and Distribution of Writing
CCSS.ELA-LITERACY.W.5.4
Produce clear and coherent writing in which the development and organization are appropriate to task, purpose, and audience. (Grade-specific expectations for writing types are defined in standards 1–3 above.)
Speaking and Listening Standards K–5Comprehension and Collaboration CCSS.ELA-LITERACY.SL.5.1
Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on *grade 5 topics and texts*, building on others' ideas and expressing their own clearly.
CCSS.ELA-LITERACY.SL.5.1.A
Come to discussions prepared, having read or studied required material; explicitly draw on that preparation andother information known about the topic to explore ideasunder discussion.
CCSS.ELA-LITERACY.SL.5.1.B
Follow agreed-upon rules for discussions and carry outassigned roles.
CCSS.ELA-LITERACY.SL.5.1.C
Pose and respond to specific questions by making comments that contribute to the discussion and elaborateon the remarks of others.
CCSS.ELA-LITERACY.SL.5.1.D
Review the key ideas expressed and draw conclusionsin light of information and knowledge gained from the discussions.
CCSS.ELA-LITERACY.SL.5.2
Summarize a written text read aloud or information presented in diverse media and formats, including visually, quantitatively, and orally.

APPENDIX L. EXAMPLE MEA ASSESSMENT RUBRIC

Making Healthy Choices Presentation Quality Rubric		**Occasionally (1 point)** (concept unclear or not applied routinely)	**Often (3 points)** (concept understood, not always applied)	**Consistently (5 points)** (concept understood and regularly applied)
Voice	● Words clearly spoken and understood ● Tone is enthusiastic, and volume is appropriate ● Each member of the group contributed to the presentation (explained slides, answered questions, etc.) ● Pauses, mistakes, and distractions are minimal			
Content	● Content is scripted with evidence of thorough development of a dietary plan based upon physical activity level and age ● Content includes: a. Description of the individuals and physical activity levels chosen b. List of meals chosen for breakfast, lunch, and dinner c. Explanation of procedure or set of guidelines used to develop presentation			
Math	● Presentation includes math, symbols, graphs, tables, words, equations, and or pictures to justify your procedure or set of guidelines			
			Total Score:	**/15**

APPENDIX M. EXAMPLE MEA IMPLEMENTATION PLAN

Example MEA Implementation Plan					
Date	**Sequence**	**MEA Activity**	**Time**	**Materials**	**Notes**
	Day 1	MEA Subject Introduction & Team Formation	45 mins		
	Day 2	Advanced Organizer/Newspaper Article & Discussion Questions/Topics	45 mins		
	Day 3	Problem Statement/Client Memo & Problem Identification	45 mins		
	Day 4	Community Partner/Student Mentorship	45 mins		
	Day 5	*Flex-day	45 mins		
	Day 6	Iteration 1 of MEA Team Solution	45 mins		
	Day 7	*Flex-Day	45 mins		
	Day 8	Iteration 2 of MEA Team Solution	45 mins		
	Day 9	Final Team Solution Presentations	45 mins		
	Day 10	Assessments	45 mins		

* Flex days are used when extra time is required.

APPENDIX N. EXAMPLE PAGE FROM MY CAREER PASSPORT

STEM Professional #1

What is the guest speaker's name?

____

____

What is the guest speaker's career (job) ?

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____

____

What is the most interesting part of the guest speaker's job to you?
Could you see yourself working in this career (job) ?

____

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____

____

____

____

STEM Professional #2

What is the guest speaker's name?

____

____

What is the guest speaker's career (job) ?

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____

____

What is the most interesting part of the guest speaker's job to you?
Could you see yourself working in this career (job) ?

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Created by M.A.L.T.S Graduate Team (2019)