HIGH SCHOOL STUDENTS' SYSTEMS THINKING IN THE CONTEXT OF SUSTAINABLE FOOD SYSTEMS

by

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May this work contribute greatly to humankind's journey
of making the world a more sustainable place.

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ABSTRACT

The world is governed by complex systems and it is inadequate to deal with complexity by simplifying it (Bawden, 1991). Therefore, higher-order thinking, especially systems thinking, is needed to help solve complex problems in society. This study addressed two major problems in the education systems. First, high school instruction does not typically support students in developing higher-order thinking (Ichsan, Sigit, & Miarsyah, 2019; National Research Council [NRC], 1988; Smith & Szymanski, 2013; Valerdi & Rouse, 2010). Second, a majority of high school students have limited knowledge and awareness of food, its social and economic significance, and its links to health and environmental quality (Ebrahim, 2016; Harmon & Maretzki, 2006; Mercier, 2015; NRC, 1988; Trexler, Johnson, & Heinze, 2000). This study used sustainable food systems as the context to facilitate the teaching of systems thinking because it offers highly complex and highly relatable educational content to students' everyday life. The opportunities to practice systems thinking are provided through learning about sustainable food systems that interact with social, cultural, political, economic, health, and environmental conditions at multiple scales (Grubinger et al., 2010). The purpose of this qualitative case study was to explore and describe high school students' systems thinking throughout a sustainable food systems learning experience, which was designed for students to practice systems thinking. Further, the researcher sought to explore how the learning experience helped students practice systems thinking and how students intended to use systems thinking beyond the learning experience.

Participants in this study were 12 high school students located in the suburban area of the central region of Indiana. Eleven students were enrolled in a food science class in a public high school and one student was enrolled in a homeschool. They participated in the learning experience using self-directed online lessons, scaffolding worksheets, reflection questions, real-world local examples, and experiential learning activities. Data sources consisted of questionnaires, assignments, and field notes, in addition to interview transcripts from a sample of six students. Data were analyzed using qualitative coding techniques. There were four conclusions for this study. First, students who demonstrated systems thinking had the following attributes: (1) they were motivated; (2) they were open-minded; (3) they were aware of holistic thinking; and (4) they had various levels and types of food systems backgrounds and

experiences. Second, students demonstrated a combination of systems thinking abilities by extensively explaining about a food system's various connections, complexity, wholeness, changeability, cyclic nature, and feedback loops in temporal and spatial dimensions using multiple perspectives. Third, systems thinkers benefited from the instructional design features in practicing systems thinking in the context of sustainable food systems and they recognized that systems thinking was challenging and time-consuming, whereas students who were not systems thinkers struggled to come up with their own answers and only benefited from learning about content knowledge and some systems concepts instead of how to think in a systems thinking way. Finally, most students recognized the benefits of systems thinking in helping them better understand complex phenomena when solving problems and performing tasks. Systems thinkers elaborated the applications of systems thinking in supporting a desirable and sustainable food system through food choices, food-related decisions, and future projects. Specifically, most students intended to purchase locally grown and raised fresh food from a farm that used natural methods and used a minimal packaging. Students shared that they would reduce food waste by eating leftovers, donating, and communicating with businesses about reducing food waste. Implications for practice and policy, and recommendations for further research were discussed based on these findings.

CHAPTER 1: INTRODUCTION

1.1 Chapter Overview

In the first chapter, I discussed the research problem through the need to increase students' opportunities in practicing systems thinking in order to solve complex problems and the need to increase knowledge about food systems. I also explained the rationale behind using sustainable food systems as the context of this study. Sustainable food systems context facilitates systems thinking by offering the complex content through promoting the understanding of the connections between an individual and food in the environmental, social, and economic aspects. In addition, this chapter consists of a problem statement, significance of this study, purpose of this study, and a list of definitions for terms used throughout this study.

1.2 Introduction

The world is governed by complex systems. When a problem occurs, it should be treated as a complex problem because interfering with one part of a system yield both intended and unintended consequences (Ponto & Linder, 2011). It is inadequate to deal with complexity by simplifying it or ignoring the interrelationships between humans and the environment (Bawden, 1991). Therefore, higher-order thinking especially systems thinking is needed to help solve these societal complex problems in the real world. With systems thinking, a person can understand the whole and its many levels of interrelationship which are parts of the complex system (Hiller Connell, Remington, & Armstrong, 2012). Unfortunately, schools in the United States are criticized that instruction does not support students to learn higher-order thinking (Ichsan, Sigit, & Miarsyah, 2019; National Research Council [NRC], 1988; Smith & Szymanski, 2013). Various researchers found that without being adequately taught to think in terms of higher-order thinking, students do not have the skills to solve complex problems (Ivie, 1998; NRC, 1988). This study addressed the need to increase the opportunities for high school students to learn and practice systems thinking.

Sustainable food systems served as the context of this study to facilitate the teaching of systems thinking. Sustainable food systems as the context offers highly complex and highly relatable educational content to students' everyday life, which also encourages relevancy

(Balschweid, 2002; Ogunniyi, 2011). This is because when students do not recognize the connections of what they learn in school with things around them, they feel that school is irrelevant, which results in not being motivated to learn (Beane, 1995; Fusco, 2001; Johnson, 2002; Kim & Frick, 2011). Another problem in education and our society is the loss of knowledge regarding food systems. Findings indicated that consumers know very little about food, crop varieties, and other processes in acquiring food (U.S. Farmers and Ranchers Alliance [USFRA], 2011; Widener & Karides, 2014). Moreover, most Americans have limited knowledge about the social and economic significance of food systems as well as the connections between food systems, human health, and environmental quality (Ebrahim, 2016; Harmon & Maretzki, 2006; NRC, 1988; Trexler, Johnson, & Heinze, 2000). Only few Americans consider food systems to have an influence on national security while food systems have a vital role in terms of affecting the physical and mental health of people, the economy, and the environment (Mercier, 2015; NRC, 2015).

1.3 Problems in the Education Systems

This study addresses two major problems in the education systems in the United States. First, many high school students lack of higher-order thinking abilities. Second, many high school students have limited knowledge about food and food systems.

1.3.1 Lack of Higher-Order Thinking Abilities

Many teachers in the United States do not focus their teaching or supporting students to learn higher-order thinking (Ichsan et al., 2019; Ivie, 1998; NRC, 1988; Smith & Szymanski, 2013) and one of the most important higher-order thinking skills is systems thinking (Draper, 1993; Hung, 2008; Wang & Wang, 2011). Higher-order thinking helped an individual make decisions about what to believe or do in a complicated situation (Lewis & Smith, 1993). Not as simple as memorization and comprehension, higher-order thinking involves a variety of cognitive processes including using abstract structures for thinking, organizing information into integrated system, and applying logic and judgment (Ivie, 1998; Wang & Wang, 2011). Various researchers found that emphasis of instruction has been put on rote memorization or fact recall to improve student achievement on standardized tests rather than problem solving, which limits students' abilities to understand and solve complex problems (Mayer, 2002; NRC, 1988; Smith & Szymanski, 2013; Valerdi & Rouse, 2010). Moreover, most instructions are largely reductionist in nature and focus on the components that make up the system rather than the integrated processes that build the system (Ben-Zvi Assaraf, Dodick, & Tripto, 2013).

As citizens and future professionals, high school students especially need to be prepared to deal with complexity and other domains outside of their specialization (Valley, Wittman, Jordan, Ahmed, & Galt, 2017). It is crucial that high school students develop higher-order thinking in order to respond to challenges of the rapidly-changing world (Wang & Wang, 2011). Without the training of higher-order thinking, especially systems thinking, students would not be able to identify relationships between system components, understand pattern of interactions, model a system, or make a prediction or retrospection regarding a system (Meilinda, Rustaman, Firman, & Tjasyono, 2018). These abilities would help students understand the whole picture, understand different levels that contribute to the causes of a problem, and find a way to enhance, improve, and solve problems in various types of systems (Arnold & Wade, 2017; Hiller Connell et al., 2012; Meadows, 2008).

1.3.2 Limited Knowledge about Food and Food Systems

Since the population shifted to the urban areas, people have lost the knowledge about food and crop varieties (Widener & Karides, 2014). To make matters worse, food, agriculture, and environmental studies are not part of the compulsory subjects taught in schools around the United States including the state of Indiana (Indiana Department of Education, 2018, 2019), which leads to more and more students being disconnected from food systems (Ebrahim, 2016; Harmon & Maretzki, 2006). In 1988, National Research Council (NRC) published a book stating a concern that the public was becoming increasingly unaware of their own food production. Most Americans had limited knowledge about agriculture, its social and economic significance in the United States, and its relations to public health and environmental quality (Ebrahim, 2016; Harmon & Maretzki, 2006; NRC, 1988, 2015; Trexler et al., 2000). A few decades later, findings still indicated that consumers knew very little about the food-to-table processes (USFRA, 2011). Only few Americans consider food and agriculture to have an influence on national security (Mercier, 2015). People forget about the need for safe, plentiful, and affordable nutritious food to feed the country and the impact that food systems have on the health of the economy and the environment (Chase & Grubinger, 2014; NRC, 2015; Vermeulen, Campbell, & Ingram, 2012).

It is important to increase the knowledge of food systems, especially among high school students who are primarily consumers and future policy supporters. Specifically, studies found that agriculturally literate Americans are more likely to support policies affecting agriculture than those lacking agricultural literacy (Dailey, Conroy, & Shelley-Tolbert, 2001; Kovar & Ball, 2013). Therefore, society can lessen those challenges through informed decisions by educating their citizens about food systems to ensure agriculturally and food systems literate people in leadership roles. For instance, lawmakers cannot be expected to make informed decisions regarding the safe and appropriate regarding food supply without being agriculturally literate (Balschweid, Thompson, & Cole, 1998).

1.4 Systems Thinking

Thinking in systems thinking way is not intuitive or innate (Hiller Connell et al., 2012; Valerdi & Rouse, 2010). Even among the population that was self-identified or implicitly assumed from their careers to have higher systems thinking competence, their systems thinking performance was poor (Valerdi & Rouse, 2010). According to the literature, this is because human evolution has favored mechanism to naturally deal with problems and make decisions by breaking them down into parts, which is called a reductionist reaction (Valerdi & Rouse, 2010; Verschuren, 2001). Even research has been reductionistic in nature since the early stage of technical sciences development and has left out the underexposed aspects of social reality (Verschuren, 2001). The findings, therefore, were simplified rather than being clarified, which caused public doubt and confusion (Widener & Karides, 2014).

It is important to distinguish the term systems thinking with other similar terms. Systems thinking is often used interchangeably with systematic thinking or systemic thinking. However, the three terms refer to different things. *Systems thinking* refers to thinking about a system as a whole and the interactions within that system (Bartlett, 2001; Kasser, 2018; Ponto & Linder, 2011). *Systematic thinking* means thinking methodically or in a step-by-step manner (Bartlett, 2001; Kasser, 2018). *Systemic thinking* is a simple technique for finding system-wide focus (Bartlett, 2001).

Systems thinking has evolved to counter mechanistic or reductionist thinking (Hiller Connell et al., 2012). It is considered a holistic approach that looks at an object as a whole, in which a whole is different from the sum of its parts (Bawden, 1991; Bawden, Macadam, Packham, & Valentine, 1984; Meadows, 2008; Valerdi & Rouse, 2010; Verschuren, 2001). Moreover, systems thinking addresses pluralism which values multiple perspectives and requires engagement with other disciplines, knowledge, and expertise outside of the academia (Valley et al., 2017). One of the most important features of the systems thinking is the concern whether the desired ends are ethically defensible (Bawden, 1991). Educators believe that when an individual fully understands systems concepts such as multiple interdependencies and unintended consequences, they will see their role in creating a sustainable future (Ponto & Linder, 2011).

1.4.1 The Use of Systems Thinking

Systems thinking is a mode of thinking which anticipates that when one part of a system is affected, other parts that connect to it are also affected resulting in unintended consequences (Ponto & Linder, 2011). There were claims that skillful use of systems thinking skills could have prevented disasters such as World War II, the Great Depression, and the Space Shuttle Challenger disaster (Arnold & Wade, 2017). Specifically focusing on the area of food and agriculture, without systems thinking, the progress in agricultural productivity has serious unfair trade-offs resulting in many problems including long-term environmental degradation; negative impacts on health and safety of farm workers and consumers; and the concentration of wealth (Bawden, 1991). For example, the herbicide-tolerant genetically modified crops increase the herbicide usage, but fail to analyze synergies and trade-offs of soil diversity (Bawden, 1991). The concern of food insecurity targets on ‘arithmetic of food supply and population’ while other interrelated dimensions such as distribution and income gap also impact availability and access (Page, 2013; Valley et al., 2017). The reductionistic view toward food insecurity issue has resulted in massive food surpluses co-existing with hunger, obesity, unsafe foods, or foods with low nutritional quality (Bawden, 1991).

Alternatively, systems thinking can be used to enhance and improve all types of systems such as health care, economy, technology, laws, institutions, and international and interpersonal relationships (Arnold & Wade, 2017) because systems thinking helps an individual identify fundamental causes of a problem as well as see new opportunities to solve them (Meadows, 2008). Specifically focusing on the area of food and agriculture, with systems thinking, the research can benefit from integrating various disciplines and direct the work toward the goals of sustainability (NRC, 2010). For example, researchers could use the concept map of ecological mechanisms in shaping the directions of their research to control soybean aphids by involving multiple strategies that incorporate the natural enemies and consider about their habitats instead of using a single solution without considering the interconnected picture (Drinkwater, Friedman, & Buck, 2016). At an individual level, systems thinking helps us reflect on how our actions, such as diet decisions, have an impact on one or more variables in a system, in order to determine whether those actions contribute to the sustainability of our environments (Ponto & Linder, 2011).

1.4.2 Systems Thinking in the Instructions of Food and Agriculture

Traditional agricultural and food-related curricula have followed linear, cause-and-effect rationalities focusing on limited range of objectives (Valley et al., 2017). They especially focused on narrow production problems (Williams & Dollisso, 1998). In these past decades, educators have attempted to incorporate systems thinking with the teaching of agricultural and food-related curricula (e.g., Bawden, 1991; Bawden et al., 1984; Brekken, Peterson, King, & Conner, 2018; Francis et al., 2011; Hilimire, 2016; Jordan et al., 2014). Systems thinking is a more useful framework in investigating and solving problems in agriculture as well as representing the real world than reductionistic, discipline-based frameworks (Bawden et al., 1984).

The philosophy proposed for teaching agriculture to include economic, social, and environmental issues (Bawden, 1991; Williams & Dollisso, 1998; Valley et al., 2017) responded to the National Research Council’s (1988, 2009) call to not only focus on optimizing inputs and returns, but also protecting the environment. For example, sustainable agriculture programs require a holistic and systems approach to solve problems in the industry by shifting the teaching about maximizing agricultural output to balancing benefits across other environmental, social, and economic issues (Valley et al., 2017).

1.4.3 Sustainable Food Systems as the Context for Systems Thinking

Today's youth will soon grow up to be parents, teachers, policy makers, community leaders, and food-related professionals who make food purchasing decisions and participate in the democratic process and will influence the character and sustainability of the food systems (Harmon & Maretzki, 2006). To practice systems thinking, sustainable food systems context offers complexity and relevance to students' everyday life. The opportunities to practice systems thinking are provided through learning about sustainable food systems that both reflect and respond to social, cultural, political, economic, health, and environmental conditions at multiple scales (Grubinger et al., 2010). Moreover, sustainable food systems context covers various dimensions of food systems including inputs (e.g., energy, natural resources, human capital), influences (e.g., beliefs, politics, climate), and outputs (e.g., by-products, economic activity, pollutants) that are often unaddressed or overlooked (Chase & Grubinger, 2014). Systems thinking helps people see the interconnections within food systems far in advance before and after the point of consumption, while utilizing this knowledge would lead to "a more just, secure, participatory, and inclusive future" (Widener & Karides, 2014, p. 675).

1.5 Problem Statement

Systems thinking is important for understanding complex phenomena and for the sustainable future of our society. However, the current education systems do not typically offer opportunities for high school students to learn or practice systems thinking as discussed in the previous section. Limited research studies regarding systems thinking have been conducted, especially among high school students. Although sustainable food systems context provides a complexity for practicing systems thinking and is directly relate to students' real world, no studies were found to examine systems thinking among high school students in the context of sustainable food systems. Therefore, the purpose of this study was to explore and describe high school students' systems thinking qualitatively in the context of sustainable food systems.

1.6 Significance of the Study

This study was significant for four primary reasons: (1) this study qualitatively explored and described how high school students demonstrated systems thinking in the context of sustainable food systems; (2) this study informed curriculum developers and educators about the instructional design for incorporating systems thinking; (3) this study addressed the needs to teach food systems and systems thinking in order to support a sustainable food system; and (4) this study highlighted the purpose of education by utilizing sustainable food systems topic that informs different aspects of complex societal issues and how to solve them.

This study was designed to contribute to education systems by qualitatively exploring and describing how high school students demonstrated systems thinking throughout the learning of different systems concepts and the practice of systems thinking in the context of sustainable food systems. The findings are important in the development of appropriate assessment methods. In addition, the curriculum developers and educators could utilize this study to organize and improve an educational program that incorporates systems thinking based on the findings about instructional design features that fostered and hindered students' learning experiences.

Regarding educational policy, this study enhanced the effectiveness of utilizing food systems as the real-world problems in the instructions because the problems in food systems affect everyone and are affected by everyone. The content knowledge regarding food and food-related issues should be incorporated in the mandatory subjects taught in schools to increase the understanding of food items that students consume as well as the connections of the food items with other sectors. In addition, this study contributed to curriculum development that could support high school students in becoming informed consumers, citizens, and future professionals who would be able to solve complex problems in society. Systems thinking is crucial in finding possibilities in managing and solving the 21st century complex problems and facilitating new ideas, concepts, techniques, and tools (Boardman & Sauser, 2008).

Regarding implications for society, students in this study learned about the real-world societal issues and how to be part of the solutions through sustainable food systems topic. The topics present these issues in terms of social, economic, environmental, and nutritional health aspects. The study supported students in making informed decisions for themselves and their communities, which meets the goal of education for students to be engaged citizens and to improve their well-being and their environment. The intellectual development in systems thinking would be an important tool for students to stay informed and make an impact to the needs of society and ultimately lead to a desirable and sustainable future (Arnold & Wade, 2015; Bawden, 1991; Ponto & Linder, 2011).

1.7 Purpose of the Study

The purpose of this study was to explore and describe high school students' systems thinking throughout a sustainable food systems learning experience, which was designed for students to practice systems thinking. Further, the researcher sought to explore how the learning experience helped students practice systems thinking and how students intended to use systems thinking beyond the learning experience.

1.8 Research Questions

Three research questions guided this study:

1. In what ways did students demonstrate systems thinking throughout the sustainable food systems learning experience?
2. How did the instructional design of this learning experience help students learn about, engage in, and practice systems thinking?
3. How did students intend to apply systems thinking beyond the learning experience?

1.9 Assumptions

1. The researcher was informed by a pragmatist paradigm. The pragmatist paradigm views knowledge as being both constructed and based on the experience of reality (Johnson & Onwuegbuzie, 2004). Pragmatist paradigm directed the researcher to use all approaches available that could solve or provide directions and possibilities in addressing the research problem and providing actionable answers (Creswell, 2014; Goldkuhl, 2012; Patton, 2015). Specifically, pragmatist paradigm guided the researcher in making pragmatic decisions within limited time and resources to adapt based on the situation and opportunities that emerged (Patton, 2015).
2. Research bias was minimized through the guidance of the expert faculty panel regarding methodology and analysis.
3. Participants completed the modules, activities, and assignments by themselves.
4. The data collected from high school students accurately reflected their honest thoughts, perceptions, and experiences.
5. The data collection methods were age appropriate for high school participants.

6. Case study was essential as a unit of analysis of a classroom to explore high school students' systems thinking throughout the sustainable food systems learning experience.
7. Participants were involved in the sustainable food systems learning experience throughout the length of the study.
8. All data were collected using reliable and valid instruments.

1.10 Limitations

1. Participants attended the sustainable food systems learning experience as part of their regular classes. Their responses might not be as thoroughly as people who would have volunteered to participate.
2. The learning experience was implemented strictly during class periods without homework assignments or reflective essays.
3. The durations of each class period were inconsistent depending on the weather conditions and other activities happening at the high school.
4. The accuracy of the data depended on the participants' honesty and willingness to elaborate their thoughts.
5. The researcher's role in developing the learning experience used in this study might lead to preconceived assumptions.
6. The researcher was not an expert in developing online lessons and had a limited time in producing the instructional materials.
7. The study was conducted by one individual in a limited time frame.

1.11 Definitions of Terms

- **Complex Problem**: The problem that is not clearly defined but involves knowledge-rich requirements and collaboration among different persons (Dörner & Funke, 2017).
- **Complexity:** The state of being messy, nonlinear, turbulent, and dynamic. It involves transient behavior, creates diversity and uniformity, and is shaped by and structured as complex feedback systems (Meadows, 2008).

- **Food Systems**: An interconnected web of activities, resources, and people in all domains involved in providing human nourishment and sustaining health, including production, processing, packaging, distribution, marketing, consumption, and disposal of food while reflecting and responding to social, cultural, political, economic, health, and environmental conditions at multiple scales (Grubinger et al., 2010).
- **Higher-Order Thinking**: The thinking that reflects three criteria: 1) using abstract structures for thinking; 2) organizing information into integrated system; and 3) applying sound rules of logic and judgment (Ivie, 1998).
- **Pro-Environmental Behaviors**: Intentional behaviors that contribute to environmental sustainability (Mesmer-Magnus, Viswesvaran, & Wiernik, 2012).
- **Real-World Problem**: An external situation that one can find in everyday life, on the job, and as a citizen, and recognize the usefulness to solve (Pollak, 1997).
- **Sustainable Food Systems**: Food systems that aim to achieve food and nutrition security and healthful diets while limiting negative environmental impacts and improving socio-economic welfare especially focusing on protecting biodiversity and ecosystems as well as providing culturally acceptable, affordable, and safe foods (Centro Internacional de Agricultura Tropical [CIAT], n.d.).
- **Sustainable Food Systems Learning Experience**: A short program consisting of online lessons, interactions with guest speakers, and experiential learning activities, that is developed for this study to teach about sustainable food systems and systems concepts. Students practice systems thinking and reflect on their learning experience.
- **System: "**A set of elements or parts that is coherently organized and inter interconnected in a pattern or structure that produces a characteristic set of behaviors, often classified as its function or purpose" (Meadows, 2008, p. 188).
- **Systematic Thinking**: A mode of thinking regarding methods in a step-by-step manner (Bartlett, 2001; Kasser, 2018).
- **Systems Thinking**: A mode of thinking that looks at a system as a whole and how parts interact with one another as well as understands nature and behaviors of a system from multiple perspectives in temporal and spatial dimensions in order to better understand complex phenomena (Bartlett, 2001; Kasser, 2018; Lee, Jones, & Chesnutt, 2017; Ponto & Linder, 2011).

- **Systems Thinking Concepts**: Concepts that have a certain meaning in addressing complex systems which enable an individual to see a system from a new perspective with long-term thinking and are essential in promoting sustainability (Ponto & Linder, 2011). Some of the commonly used concepts include:
    - **Boundary**: The arbitrary line that a systems thinker uses to separate one area from another in order to analyze or try to affect (Chase & Grubinger, 2014; Ponto & Linder, 2011).
    - **Delay**: An action that does not have an immediate effect (Meadows, 2008).
    - **Feedback**: A process in which the output of a system is fed back around to regulate the system (Ponto & Linder, 2011).
    - **Leverage Point**: "A place in a system where making a small change can result in a large improvement in the whole system" (Ponto & Linder, 2011, p. 61).
    - **Perspective**: A certain view or way of looking at a situation. In systems analysis, multiple perspectives play a role in helping an individual better understand complex issues (Ponto & Linder, 2011).
    - **Stock and Flow**: Stock is an accumulation of material or information that has built up in a system over time that increases by a flow in and decreases by a flow out (Meadows, 2008; Ponto & Linder, 2011).
    - **Time Horizon**: A length of time under consideration (Ponto & Linder, 2011).
    - **Variable**: Anything that can go up or down over time. It is used to test a hypothesis or prediction in an investigation (Ponto & Linder, 2011).

CHAPTER 2: REVIEW OF LITERATURE

2.1 Chapter Overview

To address the research problem, this chapter provides an overview of the systems thinking being defined and studied in different educational contexts with different age groups. The chapter also consisted of the review of literature regarding food systems as a topic in education and the literature that informed the development of the sustainable food systems learning experience used in this study. Furthermore, the conceptual framework used to inform this study was discussed, followed by the need for the study.

2.2 Purpose of the Study

The purpose of this study was to explore and describe high school students' systems thinking throughout a sustainable food systems learning experience, which was designed for students to practice systems thinking. Further, the researcher sought to explore how the learning experience helped students practice systems thinking and how students intended to use systems thinking beyond the learning experience.

2.3 Research Questions

Three research questions guided this study:

1. In what ways did students demonstrate systems thinking throughout the sustainable food systems learning experience?
2. How did the instructional design of this learning experience help students learn about, engage in, and practice systems thinking?
3. How did students intend to apply systems thinking beyond the learning experience?

2.4 Literature Review Methodology

This study was informed by literature across several academic disciplines using a variety of resources. Online references were found using Google, Google Scholar, *Journal of Agricultural Education*, and Mendeley direct search. Examples of searched terms and phrases used in the search engine for literature included: “system$ thinking”, “system$ thinking skills”, “system$ thinking + education”, “system$ thinking + high school”, “system$ thinking + food system$”, “food system$ curriculum”, “teaching + food system$”, “food system$ + education”, and “sustainable food system$ curriculum.”

2.5 Systems Thinking Competencies

Various authors have defined systems thinking differently. This study particularly defines systems thinking as mode of thinking that looks at a system as a whole and how parts interact with one another rather than focusing on a single part as well as understands nature and behaviors of a system from multiple perspectives in terms of temporal and spatial dimensions in order to better understand complex phenomena (Bartlett, 2001; Kasser, 2018; Lee et al., 2017; Ponto & Linder, 2011). The commonly used concepts in the field of systems thinking include variable, perspective, feedback, time horizon, delay, cause and effect relationships, boundary, structure, stock and flow, event and pattern, mental model, and leverage point (Ponto & Linder, 2011).

Several studies attempted to explain the characteristics of systems thinking. In this chapter, three studies that primarily informed this study were highlighted to discuss about their proposals of systems thinking abilities. Firstly, Valerdi and Rouse (2010) summarized and presented seven initial systems thinking competencies commonly defined across domains. The list included: (1) ability to appropriately define the “universe” that the system operates in; (2) ability to define the overall system appropriately with the right boundaries; (3) ability to see relationships within the system and between the system and the universe; (4) ability to see things holistically within and across relationships; (5) ability to understand complexity in terms of uncertainty, dynamic, and nonlinear states; (6) ability to communicate across disciplines for multiple perspectives; and (7) ability to take advantage of a broad range of concepts or methods.

Valerdi and Rouse’s list of seven common systems thinking competencies could be useful in measuring the understanding a range of major systems concepts (i.e., boundary, relationships, holism, complexity, dynamic, nonlinear, and perspective) and indicating an individual’s interactions with these concepts. Although these competencies could be assessed through their applicability, an individual might not always act or behave according to their competencies, which made it difficult to detect observable effects (Valerdi & Rouse, 2010).

From that notion, this study explored the high school students' intentions to apply systems thinking instead of observing their behaviors.

Although Valerdi and Rouse's list addressed several systems concepts, there were other major concepts that the list did not address, for instance, feedback, time horizon, and pattern (Ponto & Linder, 2011). Furthermore, the literature did not discuss the relationships among these competencies whether they would occur at the same level or need to be built upon each other. Finally, these competencies were identified from various definitions of systems thinking in the fields of engineering, management, and social science literature and were not yet tested (Valerdi & Rouse, 2010).

Secondly, Ben-Zvi Assaraf and Orion conducted a few studies (e.g., 2005a; 2010a; 2010b) that led to the development of System Thinking Hierarchical (STH) model (see Table 2.1), which have been commonly cited in the field of education. The model identified eight characteristics of systems thinking grouped into three different levels: analysis, synthesis, and implementation. In addition, each systems thinking level served as the basis for the development of the next level (Ben-Zvi Assaraf & Orion, 2010a).

Table 2.1: Ben-Zvi Assaraf and Orion's (2010b) System Thinking Hierarchical Model

Level	System Thinking Characteristics
Analysis	1. Able to identify the system's components and processes.
Synthesis	2. Able to identify simple relationships between two system's components.
	3. Able to identify dynamic relationships within the system.
	4. Able to organize the system's components, processes, and their interactions, within a framework of relationships.
	5. Able to identify the cyclic nature of systems.
Implementation	6. Able to make generalizations based on systems' mechanisms.
	7. Able to recognize hidden dimensions of the system.
	8. Able to explain relationships that involve time dimension.

The STH model implied a certain order of development and hierarchy of systems thinking. However, Ben-Zvi Assaraf and Orion (2010a) considered that there might also be other factors (i.e., motivation, teaching and learning approaches, and cognitive maturity) that could affect students individually. In terms of understanding a system, this model addressed fewer systems concepts (i.e., interactions, dynamic, cyclic, pattern, and time horizon) than the first model. In addition, systems basics addressed by Meadows (2008), such as the abilities of a system to change, adapt, respond, self-organize, self-repair or the impact of stock and flow, feedback loop, delay, and buffer, were not included in the STH model.

The concept about cycles is appropriate in the context of earth system education (Ben-Zvi Assaraf & Orion, 2010b; Scherer, Holder, & Herbert, 2017). Likewise, the sustainable food systems context would also benefit from the concept of cycles, for example, the decomposition of food can cycle back to become nutrients for growing more foods. The concept of hidden dimensions would also largely benefit the sustainable food systems context by helping high school students understand the dimensions that were often unaddressed such as influences of culture, beliefs, values, and politics (Chase & Grubinger, 2014).

Lastly, Meilinda et al. (2018) developed and tested an instrument for measuring systems thinking abilities in the context of climate change. The model consisted of four phases: phase I (pre-requirement), systems thinking phase II (basic), systems thinking phase III (intermediate), and systems thinking phase IV (coherent expert). The phases categorized 12 systems thinking indicators in the context of climate change (see Table 2.2).

Table 2.2: Meilinda et al.'s (2018) Systems Thinking Indicators (p. 3)

Phase	Systems Thinking Indicators
I (pre-requirement)	a. Able to identify components and processes in a system.
	b. Able to identify the relationship of structures and functions/roles in system components in one level of organization.
	c. Able to map climate phenomenon/concept in specific components of the climate system.
II (basic)	a. Able to analyze the relationship of concepts on one level with another level above or another level below.
	b. Able to organize components of system, processes, and interactions among them in one system frame.
	c. Able to identify process of feedback which happens to the system.
III (intermediate)	a. Able to make generalization from the pattern shaped by the system.
	b. Able to design an interaction pattern from the system components whose existence in a closed system can be detected.
	c. Able to make/develop models that illustrate the positions of all components in a closed system framework in 2D/3D whether they are horizontal or vertical.
IV (coherent expert)	a. Predict/Retrospect behaviors which appear from the system due to interactions among components in the system.
	b. Predict/retrospect the effects which appear from the existence of intervention toward the system (such as the loss/addition of system components) by using model or pattern which has been designed.
	c. Implement new system pattern based on the result of prediction/retrospection.

This model is similar to Ben-Zvi Assaraf and Orion's STH model in terms of: (1) the hierarchical order; and (2) the beginning step of identifying components and processes in a system, which is a reductionist approach to break things down into parts (Verschuren, 2001). Despite the similarities to STH model, some important systems concepts were not mentioned (i.e., dynamic and cyclic). Two new systems concepts (i.e., structure and different levels) were, however, added to this model. The four categories of phases could be useful for educators to assess students' abilities at different levels of difficulties. In addition, the authors intended for this model to assess systems thinking through students' abilities to produce deliverables by asking students to map, organize, design, develop a model, and implement a pattern (Meilinda et al., 2018).

The three models provided important dimensions for exploring systems thinking in the context of sustainable food systems. There were also other authors whose work contributed to my understanding of systems thinking competencies. These authors discussed other important systems thinking abilities that an individual should have. First, a person should be able to understand that a whole is different from the sum of its parts (Bawden et al., 1984; Bawden, 1991; Meadows, 2008; Valerdi & Rouse, 2010; Verschuren, 2001). To expand on systems behaviors and concepts, other literature also addressed systems thinking abilities to understand feedback, stock and flow, delay, cause and effect relationships, and leverage point (Meadow, 2008; Ponto & Linder, 2011). As such, the ability to recognize nature and behaviors of a system and its function should be assessed (Scherer et al., 2017).

Ultimately, systems thinking should support an individual in making decisions to change a system for desired ends (Arnold & Wade, 2015); the ends that are ethically defensible (Bawden, 1991). From that notion, in addition to exploring high school students' intention to apply systems thinking, this study explored how students justified for desired and ethically defensible ends.

2.6 Systems Thinking Development

Several studies focused on the development of systems thinking in various fields of education with different age groups including elementary school students (Ben-Zvi Assaraf & Orion, 2010b; Evagorou, Korfiatis, Nicolaou, & Constantinou, 2009; Sheehy, Wylie, McGuinness, & Orchard, 2000; Witjes, Specht, & Rodríguez, 2006); middle school and junior high school students (Ben-Zvi Assaraf & Orion, 2005a, 2005b; Keynan, Ben-Zvi Assaraf, & Goldman, 2014; Raved & Yarden, 2014); high school students (Ben-Zvi Assaraf et al., 2013; Ben-Zvi Assaraf & Orion, 2010a; Cox, Elen, & Steegen, 2017); college students (Hiller Connell et al., 2012; Lapp & Caldwell, 2012); and teachers (Ateskan & Lane, 2017; Lee et al., 2017).

There was no consensus among researchers regarding the appropriate age to introduce systems thinking in schools. Ben-Zvi Assaraf and Orion (2010b) and Evagorou et al. (2009), however, offered the empirical studies indicating that elementary school students had the potential to develop systems thinking and that the introduction of systems thinking to this age group was reasonable. However, Boersma, Waarlo, and Klaassen (2011) disagreed with the recommendation because the studies that supported the claim did not measure elementary school students' ability to "think forward and backward between concrete objects and systems models" (p. 197). In addition, Boersma et al. (2011) argued that careful preparation and basic cognitive structures should be required to make this type of instruction meaningful to this age group. To look further into how ages play a role in thinking, Piaget (1970) discussed about the type of logical reasoning, for instance, semi-logic can be found as early as in four to six years of age but the logical structures are not fully developed at the preoperational stage. When students advanced from this stage especially when they grow older, they can learn the dependency relationships and the correlation among variations (Piaget, 1970) which is a basic of systems thinking.

As the researchers did not agree upon a standard set of systems thinking competencies, the comparison between studies was challenging because different studies assessed a different set of systems thinking competencies. Nonetheless, some empirical studies gave some general ideas regarding the relationships between systems thinking and the participants' ages. For example, Sheehy et al. (2000) used computer simulations to assess systems thinking and environmental problem solving among elementary school students ages 8 to 11 and found that the older group outperformed the younger group. Ben-Zvi Assaraf et al. (2013) explored high school students' systems thinking in the context of human body system and found that students were largely incapable of achieving systems thinking beyond the primary systems thinking hierarchical level of identifying components. Similarly, Cox et al. (2017) found that high school students had difficulties recognizing relationships among components in the complex system. This is not surprising due to the complex nature of systems. Systems thinking can be challenging for students of all ages, if it is not scaffolded appropriately (Scherer et al., 2017).

Based on Fischer's Skill Theory, the early high school years are the estimated age periods for middle-class Americans to first develop the cognitive level 7, which is the high point of representational development and is a transition from concrete to abstract representation (Fischer, 1980). At level 7, an individual can think of the relation between two representational systems, while at level 6 the individual cannot yet relate various systems to one another or think of objects as being abstract (Fischer, 1980). The Skill Theory explained the challenges that younger students encounter when they try to understand complexity or the hidden dimensions in systems thinking similar to what Piaget (1970) described in different stages of thinking development. Young students might have not yet developed the cognitive skills at the level to think in abstraction (Piaget, 1970). Although it is possible that early high school students have developed this cognitive level, the current education systems do not support the kind of instructions needed for systems thinking development (Ben-Zvi Assaraf et al., 2013; NRC, 1988; Smith & Szymanski, 2013; Valerdi & Rouse, 2010).

2.7 Assessing Systems Thinking

Several studies focused on assessing systems thinking during the learning process in various contexts such as organic community garden (Witjes et al., 2006); food ethnographies (Lapp & Caldwell, 2012); ecosystem (Evagorou et al., 2009; Keynan et al., 2014); environmental problems (Sheehy et al., 2000); sustainability (Hiller Connell et al., 2012); water cycle (Ben-Zvi Assaraf & Orion, 2005a, 2005b, 2010a, 2010b; Lee et al., 2017); geography (Cox et al., 2017); energy (Ateskan & Lane, 2017); human circulatory system (Raved & Yarden, 2014); and human body system (Ben-Zvi Assaraf et al., 2013).

Assessing systems thinking has been difficult because there are no standard methods to isolate the effects of the various interventions or detect competencies being used (Valerdi & Rouse, 2010). Different literature used different types of instruments and focused their assessment on different competencies. For example, Ateskan and Lane (2017) used the context of energy and collected questionnaires and concept maps to analyze teachers' systems thinking in terms of interrelationships, sequence of events, causal sequence, pluralism, feedback, and hidden dimensions. Lee et al. (2017) used questionnaires and interviews to assess teachers' systems thinking based on Ben-Zvi Assaraf and Orion's System Thinking Hierarchical (STH) model.

Hiller Connell et al. (2012) gave sustainability challenges as a task to undergraduate students and assessed their systems thinking based on the abilities to: (1) think holistically; and (2) perceive interrelationships and resolve resulting conflicts. Lapp and Caldwell (2012) used survey questionnaires, model drawings, a final paper, and project reflections to measure systems thinking among undergraduate students using three criteria: thinking in big picture, seeking complexity and interconnectedness, and taking multiple perspectives.

Cox et al. (2017) designed a paper-and-pencil test to measure high school students' systems thinking (i.e., interconnections, wholes, feedback loops, and dynamic behavior) and the abilities to draw diagram, identify variables, describe interconnections, and extract information.

Ben-Zvi Assaraf and Orion (2005a) used Likert-type questionnaires, drawing analyses, word association, concept map, interview, repertory grid, and observations with junior high school students to develop the STH model. Ben-Zvi Assaraf et al. (2013) used word association, repertory grid, concept map, and interview to assessed high school students' systems thinking based on the STH model.

Keynan et al. (2014) used repertory grid technique to assess junior high school students' systems thinking based on the STH model. Raved and Yarden (2014) used concept map to compare seventh graders' systems thinking before and after the learning process about human circulatory system based on the abilities to: (1) recognize the system components, processes, and relationships between different levels of organization of the system; and (2) organize the systems' components and its processes within a framework of relationships.

Evagorou et al. (2009) used simulations with written tests to investigate elementary school students' development of the abilities to identify seven aspects of systems thinking: elements, spatial boundaries, temporal boundaries, subsystems, influence, changes in pattern, and feedback. Witjes et al. (2006) used three different drawings to ask elementary school students about things they saw, relationships, and what they thought would happen in the drawings to determine three levels of systems thinking: (1) the understanding of sub-systems, interactions, and input-output flows; (2) the organization to create a whole, feedback, and possessiveness; and (3) the understanding of chaos and order in a system.

In addition to the studies, other authors provided recommendations for systems thinking assessment. Doyle (1997) suggested that assessing behavioral change in systems thinking alone might not be sufficient, but cognitive changes should also be measured. Doyle critiqued how retrospective self-report of mental event in describing the thinking alteration had several validity problems. Therefore, systems thinking should be assessed by comparing controlled pre- and post-measurement of cognitive processes and mental models (Doyle, 1997). Moreover, Doyle argued that there was no compelling evidence of systems thinking being qualitatively different from other cognitive processes and concluded that systems thinking could be measured by adapting existing techniques.

Valerdi and Rouse's (2010) concern that scoring in certain competencies might not necessarily lead to action. Roychoudhury et al.'s (2017) suggested administering a test before and after teaching a curriculum and instead of relying heavily on students' self-reported perception of their skills, the assessment tools should also measure how students express their competencies by performing tasks and solving complex problems. In a similar way, Brandstädter, Harms, and Großschedl (2012) encouraged the use of concept mapping technique to assess systems thinking as it is considered external representations of mental models (i.e., internal cognitive representations of objects, ideas, events, or systems) to help an individual express conceptual understand of the underlying systems structure.

In conclusion, a variety of instruments have been used to assess systems thinking in different age groups and contexts. The focus of systems thinking competencies was different depending on the researchers' decisions. There was no commonality within the same fields or participants as discussed above. Several authors suggested that students should have the opportunity to reflect on their prior and new knowledge and experiences through the metacognition process in order to elaborate their understanding of the complex system for a more accurate assessment of systems thinking (Pintrich, 2002).

2.8 Teaching and Learning about Food Systems

I reviewed the literature regarding the learning and teaching of food, agriculture, and food systems to understand the current situation regarding sustainable food systems, the context of this study. Studies found that educators and high school students were more knowledgeable about the nutrition, food safety, and health aspects, but less knowledgeable about agriculture and food sectors (Harmon & Maretzki, 2006; Trexler et al., 2000). Furthermore, high school students were unfamiliar with the term food systems and lacked knowledge regarding the topic (Ebrahim, 2016; Harmon & Maretzki, 2006).

The literature also discussed about the benefits and values of learning about agriculture and food systems. For example, students learned practical skills and leadership abilities that could be transferred to life applications (Dailey et al., 2001; Knobloch, Ball, & Allen, 2007; NRC, 1988). The educational programs regarding food and agriculture helped students develop self-confidence and intrinsically motivated students to become involved in the learning process (Dailey et al., 2001; Joshi, Azuma, & Feenstra, 2008; NRC, 1988). Students felt that their abilities related to STEM identity and change agency were increased after food systems experiential learning (Goralnik, Thorp, & Rickborn, 2018). Food and agricultural education encouraged students to eat more fruits and vegetables and improved knowledge about sustainable agriculture (Joshi et al., 2008; Kararo, Orvis, & Knobloch, 2016). Ultimately, students who participated in programs that taught about food and agriculture were more responsible and felt more respectful of the land as they became future stewards of the environment (Joshi et al., 2008; Knobloch et al., 2007).

Integrating the topics regarding food and agriculture to other subjects increased knowledge and interests among students (Ebrahim, 2016). There are many potential opportunities in integrating the concept of food systems into existing K-12 classes. Food systems topic involves all domains in the journey of food and food-related items (e.g., packaging, containers, and tableware), people, and the environment at multiple scales within social, cultural, political, economic, health, and environmental conditions (Grubinger et al., 2010). Therefore, food systems topic could bring numerous real-world examples into the classroom as well as provide students with other skills development such as working across disciplines, ethical decision-making, critical thinking, and analysis (Frick, Kahler, & Miller, 1992; NRC, 2009).

One of the most challenging obstacles is the opportunity for teachers to integrate food systems topic in the classroom. Some teachers reported that they did not prefer the integration in their classrooms for several reasons including it took time away from preparing students for the state proficiency tests, instructional resources were not available, or teachers did not perceive the educational benefits to integrate non-required topics with academic content areas (Knobloch et al., 2007; Knobloch, 2008). Therefore, there is a need for future educational resources to address this obstacle and to include the units that also benefit the preparation for standardized testing.

2.9 Systems Thinking and Food Systems Topic

Systems thinking is a learner-directed approach (Richmond, 1993; Zaraza, 1995). This approach focuses on the learner's construction of meaning and understanding rather than the idea of teachers transmitting knowledge for the learners to take in (Cornelius-White, 2007; Richmond, 1993). This approach helps students generate a wide variety of issues regarding food systems topic to which they feel personally connected. The educator's role is to help facilitate the learning through the wide topics with relationships between an individual, the environment, and their society (Cornelius-White, 2007).

Roychoudhury et al. (2017) identified four key aspects of complex systems to consider in curriculum development: (1) the open systems, stock and flow of matter and energy, nonlinear, and feedback loops; (2) small changes disrupting the stability of a system; (3) nonlinear interactions making it difficult to determine clear causal links; and (4) hierarchical subsystems. Food systems topics can address all of these four aspects and provide specific examples to promote systems thinking. This is because the nature of a food system is complex, consists of various subsystems, receives and provides energy, and can be affected by a disruption.

Currently, a dominant thinking paradigm is the "laundry list thinking" (p. 117), similar to a multiple regression equation where the assumption is that each factor causes the effect, each factor acts independently, the weighting factor of each is fixed, and there is either a positive or a negative influence (Richmond, 1993). Systems thinking paradigm as the alternative can help learners express circular process, feedback loops, and interdependence. In addition, the systems thinking paradigm encourages the view of an ongoing, self-sustaining, dynamic process. As an interdisciplinary education, food systems education encourages reflective thinking and judgment by helping students use analysis, synthesis, and evaluation in problem-solving oriented approaches; and representing a complex view of knowledge to build the abilities to recognize, evaluate, choose among, and integrate multiple perspectives (Hilimire, 2016).

2.10 Developing Sustainable Food Systems Learning Experience

2.10.1 Teaching Systems Thinking

A few national curriculum frameworks recently called for some aspects of systems thinking. For example, the National Research Council's Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas (NRC, 2012) and the Next Generation of Science Standards (NGSS Lead States, 2013) offered frameworks for teaching and measuring the knowledge and understanding about specific systems. NGSS defined a system as an organized group of related objects or components. For grade 9-12, to investigate a system, first a student should define the boundaries and initial conditions and analyze systems' inputs and outputs; use models (e.g., physical, mathematical, or computer models) to simulate systems and interactions within and between systems at different scales; and then use models to predict systems behaviors (NGSS Lead States, 2013).

Additionally, the Framework for K-12 Science Education suggested that students should have the ability to analyze and understand complex systems in terms of component parts and their interactions within a system as well as inputs, outputs, and processes (NRC, 2012). It is important to learn the basics that one thing affects another and move on to more explicit realizations of a system's physical, chemical, biological, and social interactions (NRC, 2012). Although, the National Council for Agricultural Education also produced a document for agriculture, food, and natural resources career cluster standards addressing several systems for the career pathways, there were standards for teaching critical thinking, which is another type of higher-order thinking, but no standards for teaching systems thinking (The Council, 2015).

Teachers' Guidebook for Applying Systems Thinking to Environmental Education Curricula (Ponto & Linder, 2011) identified several essential concepts in systems thinking that help an individual understand complex systems in terms of boundary, cause and effect relationship, circular causality, delay, event, feedback, flow, leverage point, mental model, pattern, perspective, stock, structure, time horizon, and variable. "These sophisticated concepts enable learners to gain new insights and give greater access to long-term thinking, which is essential to promoting sustainability of all kinds" (Ponto & Linder, 2011, p. 1).

2.10.2 Sustainable Food Systems Educational Content

Topics regarding food create meaningful learning because of the direct personal connections people have with food as well as the sense of ownership and control over the knowledge (Galt et al., 2013). It is important to emphasize these connections to students during the learning process. The curricula regarding food systems should encourage informed food choices and positive local action among learners (Harmon & Maretzki, 2006). The characteristics of a course regarding sustainable food systems were suggested to be progressive, integrated, experiential, interdisciplinary, and systems-based (Parr, Trexler, Khanna, & Battisti, 2007). Systems thinking in the context of food systems helps learners define food systems as the object of inquiry that is "a series of complex, multi-scalar relationships" (Hilimire, 2016, p. 228). More importantly, relationships between components should be explicitly taught (Cox et al., 2017).

A Delphi study regarding the development of a food-related curriculum found that students needed knowledge about natural science (i.e., soil science and ecology) and social science (i.e., policy and food systems) and that teaching about sustainable agriculture should focus on ecological processes within agricultural systems and environmental impacts of agriculture (Parr et al., 2007). To be different from school-based agricultural education, food systems curricula should emphasize global, structural, and sociocultural perspectives (Hilimire, 2016). The variation in the components of food systems should consider both natural and anthropogenic aspects (Roychoudhury et al., 2017). In addition, the curricula should also address biophysical and social structures, and materials (Widener & Karides, 2014).

The content knowledge in food systems curricula should include issues related to a food journey (i.e., food production, processing, distribution, consumption, and disposal of food and food-related items) and associate inputs to and outputs from these processes as well as the influence of social, political, economic, and environmental contexts to the issues addressed (Chase & Grubinger, 2014; Gillespie & Gillespie, 2000; Hilimire et al., 2014; Parr et al., 2007). Moreover, it is important to teach about the connections of the food journey with health, livelihoods, and the environment (Hilimire, 2016). In addition, a study by Hilimire and McLaughlin (2015) found that students expressed interests in learning about food systems in the notion of sustainability and organic.

The Wisconsin Food Systems Education Conceptual Framework (WCEE & UW Extension, 2015) generated a set of concepts for teaching food systems education to K-12. The conceptual framework included four areas: (1) fundamental knowledge about food systems and interrelationships between humans and the environment; (2) explanation regarding food origins and sourcing to create the understanding of the context behind diversity and availability of foods; (3) the importance in learning about food systems and the connections between humans and food; and (4) issues and trends within the food systems and sustainability concepts for the consideration of the future of humanity and the planet.

Teacher College Columbia University produced a series of textbooks under the Linking Food and the Environment (LiFE) collaborative project that focused on using inquiry-based activities to teach about health, food systems, and the environment. The book, Farm to Table and Beyond (Koch, Calabrese Barton, & Contento, 2008), addressed topics in food science such as knowing about the biology of ingredients and microbiology; food processing and distribution such as packaging and transportation; environmental effects such as natural resources and climate change; and waste such as inventory and management. Farm to Table and Beyond especially introduced learners to the concepts about the connectedness between biological world and human-designed world. It also encouraged life-changing decisions and commitment after teaching about health, societal, and environmental impact of activities related to food systems.

The Indiana Academic Standards for Environmental Science (Indiana Department of Education, 2018) also addressed key important content knowledge that help foster the learning of sustainable food systems as a complex system in the environmental, social, and economic aspects. For example, the standards suggested that the teaching of content knowledge should address: (1) how human activities can deliberately or inadvertently alter ecosystems; (2) the significance of great diversity of species in the event of major global changes; (3) implications of genetic engineering on the environment and society; (4) the effects of environmental stressors (i.e., herbicides and pesticides) on plants and animals; (5) the major air pollutants and their sources and impacts; (6) the product life cycle and waste stream as well as its implications to waste management; and (7) trade-offs of agricultural technology.

2.10.3 Pedagogical Approaches

Systems thinking is complex in nature. Several pedagogical approaches should be used to scaffold students' understanding. For example, Jordan et al. (2014) derived Kolb's Learning Cycle to identify learning outcomes for food systems educational programs that also give the opportunity to practice systems thinking by implementing deep reflection, rich observation and model making, future visioning and design, and responsible participation. The curricular elements that were suggested to enhance the programs include using narrative pedagogy across the curriculum because stories can help build trust and provide inspiration while learners make contextual links with academic material, resulting in more relevant and accessible learning (Jordan et al., 2014).

Simulations can also be used as experiential learning activities to develop systems thinking because simulations help students understand complex situations in terms of interactions over time at different spaces (Jordan et al., 2014). Simulations mostly did not need language or complex mental models of an environmental system because learners can see the system working on the screen (Sheehy et al., 2000). In addition, other similar types of experiential learning activities such as coaching or games were also recommended (Valerdi & Rouse, 2010).

Reflective essays directly draw out students' meaning making that cannot be easily collected through another method (Galt et al., 2013). As assignments, reflective essays reinforce experiential learning, assist learners in inquiring summatively about their cognitive, affective, or behavioral changes, and allow the instructors to understand students' experiences regarding the learning (Galt et al., 2013). More importantly, reflective judgment is helpful for the learners in solving ill-structured or complex problems of the whole system rather than isolated disciplines (Lattuca, Voigt, & Fath, 2004).

Other examples of teaching formats that were recommended include hands-on experiments, readings, physical models, visuals, and extant data about the agriculture sector (Hilimire, 2016; Roychoudhury et al., 2017; Valley et al., 2017). Food systems knowledge and attitudes that support the idea of sustaining the local food systems were found to be positively associated with participation in agricultural hands-on experiences (Harmon & Maretzki, 2006).

Lastly, Hilimire et al. (2014) suggested an exposure-first model in the introductory level for teaching about the complexity of food systems locally. The pedagogy strategies of what should be taught were suggested in the following order: (1) early initial exposure to the complexity of food systems or exposure first; (2) case study learning approaches to frame the problems; (3) experience-based learning; and (4) cooperative group learning or participatory with peers or professionals.

2.11 Conceptual Framework

I developed the conceptual framework presented in this section to illustrate how the sustainable food systems learning experience facilitated high school students in demonstrating or developing systems thinking (Figure 2.1). From the notion that learning is an active process where learners construct new ideas or concepts based on their past knowledge (Bruner, 1966), high school students' background and prior experiences related to food systems content knowledge and systems thinking were identified. Background and prior experiences were an important component that students used during the sustainable food systems learning experience as well as being a component that influenced students' systems thinking. The sustainable food systems learning experience was developed for this study to give students the opportunities to practice systems thinking. Key components that facilitated the learning included: (1) systems concepts embedded in each lesson; (2) food systems as the content knowledge and the context of real-world complex system; and (3) the instructional design features to facilitate the integration between the first two components.

Focusing closely on the instructional design features of sustainable food systems learning experience, high school students went through online instructional materials using the Food Systems Thinker website at their own pace with minimal or no presence of a teacher (Kim, 2009). This teaching approach prevented the need for a teacher professional training in teaching sustainable food systems and systems thinking. Real-world local examples were presented throughout the online lessons to increase the relevancy for students (Balschweid, 2002; Ogunniyi, 2011). Worksheets were used for each lesson as a scaffolding strategy and to engage students into thinking along with and understanding the instructional materials. Scaffolding is an important process that assists learners to construct new knowledge, challenge incomplete or wrong concepts, or recall forgotten information (Holton & Clarke, 2006).

After the website, students participated in several experiential learning activities where students visited the fields and the communities to understand the local context regarding location-specific challenges and specificity of solutions (Francis et al., 2011). Finally, reflection questions were included throughout the sustainable food systems learning experience to help organize the experiences into a representational form and transform the original cognitive structure (Fosnot & Perry, 2005). The opportunities of reflection increase the learning to become more meaningful and allow students to express their perceptions and interpretations toward the experience (Fosnot & Perry, 2005).

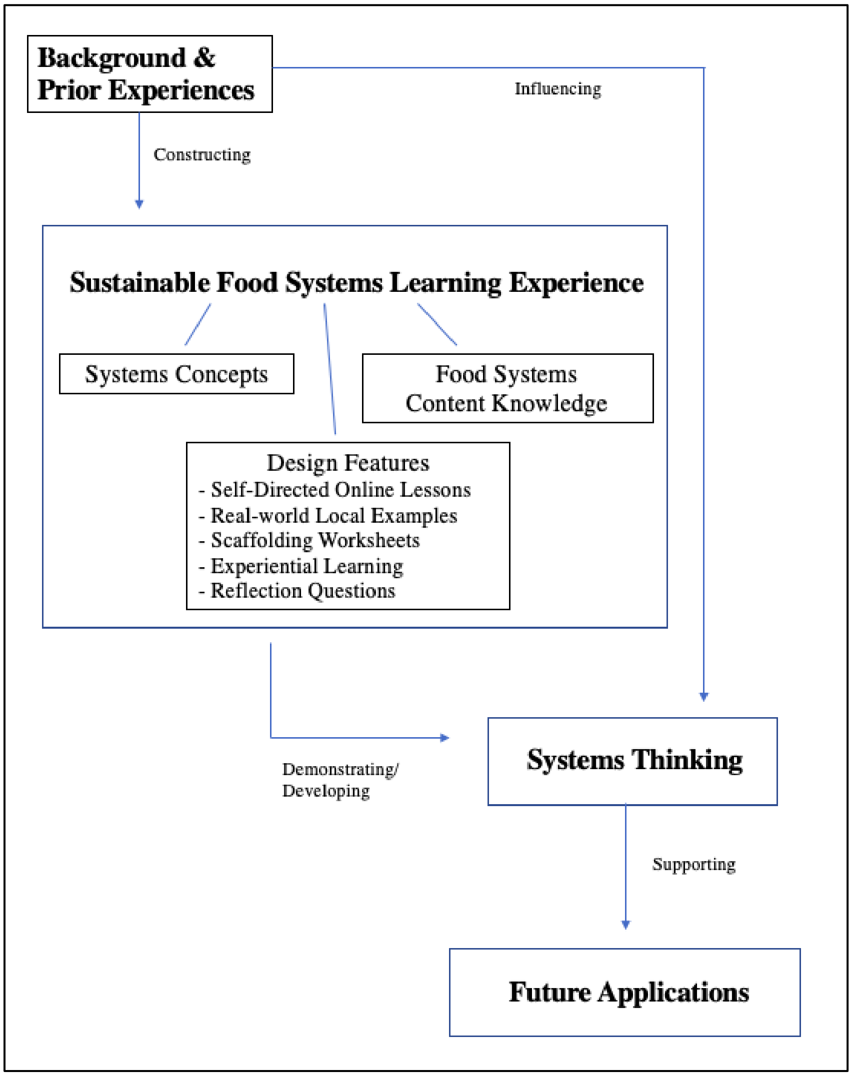

Figure 2.1: Conceptual Framework for the Study

The two final components were students' systems thinking and how students intended to apply systems thinking in the future. The conceptual framework illustrated the importance and relationships of each component in this study to answer the three research questions by exploring students' systems thinking throughout the sustainable food systems learning experience, describing how they demonstrated systems thinking, discussing their perceptions toward the learning experience and how the instructional design features engaged them into practicing systems thinking, and describing how students intended to apply systems thinking beyond the learning experience. Ultimately, systems thinking that students demonstrated or developed through the sustainable food systems learning experience could support their future application in making decisions as a consumer and/or producer.

2.12 Need for the Study

This study addressed the gap in the literature regarding the need for a study to qualitatively assess systems thinking in the United States, on high school students, and using sustainable food systems context. Limited research studies regarding systems thinking have been conducted, especially among high school students. In the United States, systems thinking literature have been limited to the definitions of the term, the importance to develop systems thinking, and suggestions for future studies (e.g., Arnold & Wade, 2015, 2017; Bawden, 1991; Bawden et al., 1984; Konkarikoski, Ritala, & Ihalainen, 2010; Richmond, 1993; Roychoudhury et al., 2017; Scherer et al., 2017). Moreover, the researchers did not agree upon a standard set of systems thinking competencies or instruments to assess systems thinking as addressed earlier. Therefore, more research and qualitative data are needed to establish appropriate assessment instruments and teaching approaches in order to provide sufficient information about the development of systems thinking.

In terms of the context, food systems curricula have not been widely available for teaching high school students. This study can be of interest to a broad range of educators in the disciplines of food, agriculture, and environmental sciences. It can also offer more available food systems resources to meet teachers' needs (Knobloch et al., 2007). The food systems educational programs have been offered only to undergraduate students in the past decade (Jordan et al., 2014). More studies are needed to improve the emerging programs. There exist similar programs being offered to high school students including the farm-to-school programs. However, there has not been a lot of evaluation on the educational benefits of farm-to-school programs (Harmon & Maretzki, 2006). Most of the evaluation and studies were progress or evaluation reports for funding agencies. Only four of 38 evaluation reports and studies were peer-reviewed and three of those did not address program outcomes and impacts (Joshi et al., 2008). Food systems topic has a lot of potential to be a context for teaching systems thinking (Jordan et al., 2014; Hilimire, 2016; Lapp & Caldwell, 2012; Valley et al., 2017). From another perspective, systems thinking is needed to address issues in food systems (Bawden, 1991; Bawden et al., 1984; Drinkwater et al., 2016; Jordan et al., 2014; Richmond, 1993). Food systems context provides a complexity for practicing systems thinking and is directly relate to students' real world. However, no studies were found to examine systems thinking in this context. Therefore, this study contributes to the body of literature on systems thinking in the context of sustainable food systems.

In terms of participants, high school students are in the critical age that have higher potential to develop higher level of thinking (Fischer, 1980). Also, high school students will soon graduate from the school systems and move on to postsecondary education or find employment and need to perform the tasks that involve solving the real-world problems. They will soon grow up to be parents, teachers, policy makers, community leaders, and food-related professionals who make food purchasing decisions and participate in the democratic process and will influence the character and sustainability of the food systems (Harmon & Maretzki, 2006). However, only three studies regarding systems thinking conducted on high school students were found (e.g., Ben-Zvi Assaraf et al., 2013; Ben-Zvi Assaraf & Orion, 2010a; Cox et al., 2017). It is important to make sure that more research is available to better promote systems thinking in the context of food systems among this age group.

2.13 Chapter Summary

This chapter included the literature review methodology, purpose of the study, and research questions. This chapter also provided the overview of literature regarding systems thinking in education in terms of the characteristics of systems thinking described in different perspectives including the focus on the understanding of the nature of a system, the hierarchical development of systems thinking, and the learner's educational products to indicate systems thinking. In addition, literature about the assessment of systems thinking in different educational contexts and age groups were discussed. Most of the studies were conducted outside of the United States and only one was about food systems at the undergraduate level.

To address sustainable food systems which is the context for this study, this chapter summarized literature about the existing knowledge, attitude, and perceptions regarding food and agriculture especially among high school students to create the understanding of the current situation in the field. The literature addressing systems thinking in the context of food and agriculture learning and teaching were discussed as the rationale for selecting the context of this study. In addition, literature that helped develop sustainable food systems learning experience used in this study were reviewed. This includes the literature specifically using food systems as a teaching topic and literature regarding food systems curricular development. The frameworks for teaching systems thinking were addressed through the documents from NRC and NGSS as well as Teachers' Guidebook for Applying Systems Thinking to Environmental Education Curricula (Ponto & Linder, 2011).

The conceptual framework that guided this study was described extensively in this chapter. The conceptual framework illustrated the components and the relationships between high school students' background and prior experiences, the sustainable food systems learning experience, students' systems thinking, and their intentions of future applications of systems thinking. Finally, the need for the study in terms of participant, context, method, and location was discussed in this chapter.

CHAPTER 3: METHODS

3.1 Chapter Overview

This chapter provides an explanation of the research methods and procedures employed to conduct this study. Specifically, a qualitative case study research design and the rationale for choosing this approach to address the research questions along with the researcher's positionality were described. I explained about the case description, participants in the study, data collection, data management, data analyses, and how trustworthiness of the study were ensured. In addition, the limitations of the study were included at the end of this chapter.

3.2 Purpose of the Study

The purpose of this study was to explore and describe high school students' systems thinking throughout a sustainable food systems learning experience, which was designed for students to practice systems thinking. Further, the researcher sought to explore how the learning experience helped students practice systems thinking and how students intended to use systems thinking beyond the learning experience.

3.3 Research Questions

Three research questions guided this study:

1. In what ways did students demonstrate systems thinking throughout the sustainable food systems learning experience?
2. How did the instructional design of this learning experience help students learn about, engage in, and practice systems thinking?
3. How did students intend to apply systems thinking beyond the learning experience?

3.4 Qualitative Methodology

The researcher employed a qualitative approach because the study took place in a real-world setting instead of a laboratory and what was observed and studied happened naturally instead of being controlled or manipulated by the researchers (Merriam & Tisdell, 2016).

Investigations were informed by the review of discipline-specific literature to design the inquiry and interpret the data (Merriam & Tisdell, 2016). Based on the characteristics of qualitative research, as the researcher, I served as an instrument for data collection and analysis, employed an inductive investigative strategy, and produced a rich description (Denzin & Lincoln, 2011; Merriam & Tisdell, 2016; Saldaña, 2015). As a qualitative researcher, I explored the participants' interpretations of their experiences and how they constructed their world in order to understand their perspectives and provided insights (Merriam & Tisdell, 2016; Patton, 2015). I occasionally visited the class and had a close relationship with my case as well as the situational constraints that shaped inquiry (Denzin & Lincoln, 2011). By nature, qualitative research permits a researcher's personal signature in the research design, implementation, and write-up (Saldaña, 2015).

Qualitative data collected for this study were primarily audio and textual materials documenting students' experiences in social action and reflexive states (Saldaña, 2015). Evidences were gathered to inductively build concepts, hypotheses, or theories rather than deductively testing hypotheses (Merriam & Tisdell, 2016). To analyze the qualitative data, I primarily focused on formatting, condensing, arraying, and constructing data, codes, categories, themes, assertions, and narratives (Saldaña, 2015). As a qualitative researcher, I valued rich descriptions of individual experiences in the social world to communicate what they had learned about a phenomenon unlike the statistical analysis that attempts to develop generalizations (Denzin & Lincoln, 2011). Quotes from interview transcripts and students' assignments were included to support the findings, which contributed to the descriptive nature of qualitative research (Merriam & Tisdell, 2016).

The research questions that ask to understand experiences called for a qualitative design (Merriam & Tisdell, 2016). In addition, the literature suggested that qualitative analysis is useful to understand students' systems thinking (Hiller Connell et al., 2012). Therefore, qualitative methodology was an appropriate approach in addressing the research questions in this study in order to explore students' systems thinking, their perceptions of the sustainable food systems learning experience, and their intentions to apply systems thinking in the future. A qualitative approach helped me explore and understand how high school students interpreted their experiences, how they constructed their understanding of food systems, and what meaning they attributed to their learning experiences.

3.4.1 Case Study

A qualitative case study was used to answer the research questions. A case study is the study of the particularity and complexity of a single case within a boundary to understand its activity within important circumstances (Stake, 1995) where researchers focus on contextual understanding and providing insights of an issue within the case (Creswell, Hanson, Plano Clark, & Morales, 2007; Jones, Torres, & Arminio, 2014; Merriam & Tisdell, 2016). Specifying a case can be done by taking into consideration of behavior patterns and boundedness where there is a limit to the number of people involved in a bounded phenomenon in a finite time (Merriam & Tisdell, 2016; Stake, 2003).

As a researcher using a case study approach, I explored a bounded system using detailed, in-depth data collection from multiple sources of information and reported a case description and case-based themes (Creswell et al., 2007; Merriam & Tisdell, 2016). I spent extended time (approximately 15 hours) on site and in contact with activities and operations of the case to reflect and revise meanings of what happened in the case and concentrated on understanding the case's complexities (Stake, 1995, 2003). Ultimately, my goal was to assist readers in constructing knowledge of the reported case (Stake, 2003).

For this study, a bounded system was an educational program, the sustainable food systems learning experience. The unit of analysis (Merriam & Tisdell, 2016) was the program being implemented during the spring 2019 semester to a group of 12 high school students at two locations (11 students at a high school and one student at a homeschool) in the suburban area of the central region of Indiana. Drawn from the case, six students were selected as a sample to build in variety and acknowledging opportunities for intensive study of the phenomena (Stake, 2003). Specifically, this study employed an instrumental case study method where a particular case was examined to provide insights into an issue (Stake, 1995, 2003).

3.4.2 Researcher's Positionality

In qualitative research, researchers serve as the primary instrument of data collection and analysis (Merriam & Tisdell, 2016). Positionality influences researchers' decision making, relationships established between researchers and participants throughout the research process, and how researchers re-present the participants (Jones et al., 2014). Therefore, as the researcher for this study, I needed to be aware of my positionality, which would describe the relationship between me and my participants as well as the relationship between me and the research topic.

My beliefs about knowledge and research resonated with a pragmatist paradigm. The pragmatist paradigm views knowledge as being both constructed and based on the experience of reality (Goldkuhl, 2012; Johnson & Onwuegbuzie, 2004). The emphasis of pragmatism is put on the nature of experience toward reality rather than the nature of reality (Creswell, 2014). As a theoretical perspective, pragmatism informed my methodological choices by supporting the decisions to choose methods and procedures that worked best for answering the research questions (Johnson & Onwuegbuzie, 2004). For this study, I considered all approaches available that could solve or provide directions and possibilities in addressing the research problem and providing actionable answers within limited time and resources based on the situation and opportunities that emerged (Creswell, 2014; Goldkuhl, 2012; Patton, 2015).

As for my previous experiences, I first studied qualitative research methodology during my master's degree, but did not have a chance to conduct a qualitative research. As a doctoral student, I took classes regarding qualitative research and completed the qualitative research graduate certificate program. Besides this dissertation, I conducted qualitative research as a graduate research assistant and co-authored two proceedings and two journal articles. I conducted research to try to understand the reasons behind a phenomenon or a decision. I believed that people make a choice to do something they think is right specifically for and to them based on their beliefs or background. However, if they do things that are not right for them, I believed that there must be a reason related to their current situation for which I seek to find an explanation (e.g., a student could not complete a class assignment because they were starving and distracted.)

I also believe that researchers, including myself, conduct research to contribute to improving our societies through the understanding of the meaning of social phenomena (Ponterotto, 2005). The goal for this research was to explore and describe high school students' systems thinking in the context of sustainable food systems through a curriculum that I developed. I hoped that promoting systems thinking among students would lead to the awareness of the world around them as a whole and not as individual segments. Especially in this context, I hoped that students would make informed decisions regarding food they purchase and consume with the consideration of minimizing the consequences on environmental, social, and economic systems as much as possible.

My research topic for this study was heavily influenced by my previous experiences. When I was in elementary school, I started participating in various activities at an urban development organization founded by my parents to address human impact on the environment. I then studied environmental science for my bachelor's degree and took an internship as an assistant field instructor after graduation. This experience narrowed my passion into promoting pro-environmental behaviors that led to promoting sustainable food systems. During my master's degree in environmental education, I focused my teaching and curriculum development on addressing the environmental impacts of food systems. Since then, I have taught students in various ages about food systems in several formal and non-formal settings including spring break camp, summer garden camp, graduate course, and field trip sites. My dissertation was funded by a Sustainable Agriculture Research and Education (SARE) Graduate Student Grant Program to develop the sustainable food systems learning experience for high school students.

Systems thinking was a new term for me two years ago when my advisor brought it to my attention. I reviewed literature about systems thinking for my independent study. The values of systems thinking aligned with my passion to support pro-environmental behaviors and sustainable food systems. Although, there is no consensus of systems thinking definition, I viewed it as a way of thinking to make connections of everything at different time horizons as part of a whole and a bigger system. I believe that without systems thinking, people are limited in thinking about the consequences of their actions, which lead to complex societal problems. I used the content knowledge of sustainable food systems in environmental, economic, and social pillars to help students practice systems thinking for this study (see section 3.5.3).

For this study, my main role was a researcher, but I also designed and co-facilitated the learning experience. I had the opportunity to socialize with the participants occasionally and build rapport with them especially during the field trips. I shared a few of my experiences regarding food and food systems with them when being asked. I administered the questionnaires and Applesauce assignments, and conducted a one-on-one interview with participants before and after the learning experience. From this study, I hoped to understand high school students' systems thinking in the context of sustainable food systems, find out about their perceptions toward the learning experience for further improvement, and contribute the findings to the field of systems thinking education and food systems education.

3.5 Data Collection

The appropriate data collection practices for a case study include collecting data from multiple sources such as documents, archival records, interviews, direct observations, participant observations, and physical artifacts (Creswell et al., 2007; Merriam & Tisdell, 2016). I collected data from multiple sources to enable triangulation (Stake, 1995). In this section, I discussed the case description, study participants, sustainable food systems learning experience, data sources, and data collection methods.

3.5.1 Case Description

To recruit participants for this study, I sent out an invitation to public high school agriculture teachers and homeschool associations within the central region of Indiana to offer the sustainable food systems learning experience. The two reasons I invited agriculture teachers and homeschool teachers were because I anticipated that: (1) they would be interested because the content knowledge of the learning experience could be applied directly to their class; (2) they had a flexibility to accommodate the learning experience into the schedule; and (3) their students were close enough to participate in the experiential learning activities because they were located within 30 miles of the university. One public high school teacher who taught a food science class and two homeschool teachers enrolled their students in the sustainable food systems learning experience. There were 15 students participated in the learning experience, but only 12 students completed the program and were eligible to participate in this study.

The case for this study was within a bounded system of a sustainable food systems learning experience—an educational program implemented during the spring 2019 semester to a group of 12 high school students in the central region of Indiana. Eleven public high school students were enrolled in a food science class in a mid-size suburban school. The class was the second half of a year-long program taught by a female agriculture teacher. The course aimed to help students understand the role that food science plays in securing a safe, nutritious, and adequate food supply. The school enrolled approximately 1,800 students from grade 9th to 12th.

The student body of the high school was 52% male and 48% female, and the total minority enrollment was 20%. The student population was 80% White, 11% Hispanic, 3% Black, 3% Asian, 0.3% American Indian/Alaskan Native, and 2.7% multiracial. About 25% of the students were economically disadvantaged (i.e., participating in the free/reduced lunch program).

Additionally, one high school student was a homeschool student living in the same area of the central region of Indiana. The family was white and there were four other siblings attending the homeschool. The mother served as the teacher in planning for the student's classes and assignments. The student was given a flexible schedule to complete a daily task list of different subjects including mathematics, history, foreign language, chemistry, writing, English, vocabulary, and agriculture/engineering. The homeschool student participated in all of the field trips with the public high school students.

3.5.2 Study Participants

All 12 study participants for the study returned a signed parental consent form and a signed assent form to be in the study. They completed at least 75% of the learning experience. Their demographic characteristics were reported for gender, race and ethnicity, grade, type of classroom, and economic status (Table 3.1). A sample was drawn from these 12 students for intensive study (Stake, 2003). Six students did not have a scheduling conflict and were available to be interviewed for the intensive study. They were assigned a fruit name for pseudonym. Unintentionally, this group of six students offered a balance of gender and grade, in which they assured variety, but were not necessarily representative (Stake, 2003).

Table 3.1: Demographic Characteristics of Study Participants

Pseudonym	Gender	Race/Ethnicity	Grade	Classroom	Free/Reduced Price Meals
Apricot*	Female	White	11	Public School	Yes
Arugula	Female	White	12	Public School	Yes
Blueberry*	Male	White	12	Public School	No
Edamame	Unknown	White	11	Public School	No
Ginger	Female	White	11	Public School	No
Jujube*	Female	White & Asian	11	Public School	No
Jalapeño	Female	Asian	12	Public School	No
Kale	Male	White	11	Public School	No
Kiwi*	Male	White	10	Public School	No
Nectarine*	Male	White	10	Homeschool	No
Raspberry*	Female	White	12	Public School	Yes
Spinach	Male	White	11	Public School	No

***** Students assigned a fruit name were in the intensive study.

3.5.3 Sustainable Food Systems Learning Experience

The sustainable food systems learning experience served as the common experience among the participants in the case. It was developed and implemented to increase high school students' knowledge and understanding about food systems in the aspects of environment, economy, and community as well as provide the opportunities for practicing systems thinking in the context of sustainable food systems. More specifically, the learning experience aimed to increase students' knowledge about sustainability and foster systems thinking by engaging them to learn about how their food choices had an impact on the environment, economy, and community and the importance of supporting a sustainable food system.

I developed the curriculum with input from an advisory panel of six experts in the fields of agricultural education, diversified farming and food systems, local food systems outreach, systems thinking education, environmental education, and curriculum and instructional design. Approximately six months were spent identifying resources, interviewing farmers, producing videos, creating content, developing worksheets, and designing the website. The development of the sustainable food systems learning experience was financially supported by the North Central Region Sustainable Agriculture Research and Education (NCR-SARE) Graduate Student Grant USDA-NIFA project # 2016-38640-25381, NCR-SARE project # GNC18-256. The grant covered part of my time commitment, compensation to farmers and a classroom teacher, travel mileage, educational resources, and expense during the field trips.

A conceptual guide to food systems education (WCEE & UW Extension, 2015) and a complex diagram of the food systems (Chase & Grubinger, 2014) were used to structure self-directed online educational resources and experiential learning opportunities for high school students. The pedagogy strategies for teaching food systems were also used through exposing students with the context of food systems, case study learning from the real-life examples, and interactions with practitioners as guest speakers (Hilimire et al., 2014). The design principles for learning about complex systems were incorporated in the development of the sustainable food systems learning experience through offering experiential learning activities, teaching systems concepts, and supporting reflective writing (Ben-Zvi Assaraf & Orion, 2005; Galt et al., 2013; Harmon & Maretzki, 2006; Ponto & Linder, 2011). The advisory panel and high school teachers reviewed the online resources after they were developed. Changes were made to the online resources based upon the feedback.

Next, I will explain how the sustainable food systems learning experience was implemented chronologically. First, students completed the Applesauce assignment (see Appendix D). Applesauce was chosen as a specific context because it is a commonly known food in the United States. Students were instructed to explain how the life cycle of applesauce from growing an apple tree until throwing away a container is relevant to different dimensions of food systems including inputs, food production and distribution, health and well-being, environmental impacts, influences, and outputs at multiple scales (Chase & Grubinger, 2014; Grubinger et al., 2010). The purpose of this assignment was to ask students to demonstrate their systems thinking and knowledge about food systems before the sustainable food systems learning experience began. After the last lesson, students were asked to complete the Applesauce assignment again to demonstrate their systems thinking and knowledge about food systems after participating in the sustainable food systems learning experience.

Students navigated through 10 self-directed online lessons (see Table 3.2) where instructional content in each lesson were presented in the formats of readings, slideshows, audio files, and videos. Five educational videos were produced for the lessons from the interviews with five local farmers presenting real-life examples of food systems-related issues. Specifically, biodiversity, seed saving, disruption of food transport, sustainable practices, labor injustice, local economic development, and power of consumers were discussed. Systems concepts were highlighted in each lesson and incorporated in the worksheets to help students practice systems thinking. The lessons fostered the practice of systems thinking through identifying components and relationships within a food system and with other systems, setting boundaries for systems analysis, considering different perspectives and variables, recognizing concepts of stock and flow, feedback, and leverage points, and understanding about delay and time horizon (Ponto & Linder, 2011).

Ten worksheets (see Appendix G) were developed to guide students through each online lesson, scaffold their learning, engage students with the content knowledge provided on the screen, stimulate the practice of systems thinking, and direct students to reflect on their thinking and their experiences related to issues in food systems. Students responded to reflection questions that asked for their personal opinions, their experiences, and what they would do in a similar situation. In addition, students were asked to reflect on what they found useful about the lesson and what they thought could be improved in each lesson by documenting their thoughts on the worksheets.

Students participated in experiential learning activities for deeper understanding of sustainable food systems in the local context and practicing systems thinking (see Table 3.2). Students interacted with four guest speakers: an urban farmer, a seed saver, a food systems professor and researcher, and a diversified organic farmer. The guest speakers provided insights on sustainable food systems in the local area. Students went on two field trips and participated in hands-on activities (i.e., volunteering at a food pantry, using reusable tableware during lunch, visiting a university student farm, visiting a diversified organic farm, and planting seedlings).

Table 3.2: Online Lessons and Experiential Learning Activities

Lesson	Description
1. A Whole and Its Components	Identification of components and relationships in a food system. Recognizing the wholeness and a bigger picture of a food system.
2. Levels of Food Systems	Boundary for analysis of a food system at six levels from individual to global scale. Interaction with an urban farmer in the local area.
3. Interactions with Other Systems	The dynamics of food systems with other systems such as ecosystem, political system, economic system, climate system, cultural system, and health system.
4. Key Players	Roles of different actors in food systems and various perspectives toward a food system.
5. The Influencing Forces	Variables influencing and affecting on, influenced and affected by a food system.
6. Impact of Food Systems	Inputs, outputs, stock, and flow in a food system.
7. Food Waste	The problem of food waste and what a student can do personally to alleviate the problem.
8. Climate Change and Biodiversity	The delay of climate change effects. Interaction with a farmer and seed saver on how to use biodiversity to reduce the effects of climate change.
9. I'm a Consumer/Citizen.	Discussion about feedback in a food system and how to support a sustainable food system.
10. Working Together	Discussion about time horizon and how a community garden could address food insecurity.
Field Trip 1	In the morning, students learned about food insecurity in the local community, witnessed the operation of a food pantry, and volunteered at the food pantry. Students had lunch from a catering service and used reusable tableware. In the afternoon, students visited a university student farm, interacted with a farm manager and a professor/farmer who taught food systems to learn about agricultural majors, small farm operation, and systems thinking. Students walked through farm structures and explore farm spaces.
Field Trip 2	Students visited a diversified organic farm, interacted with the farmer about the operation and challenges on the farm, witnessed a small-scale composting operation, and had an up-close exposure to farm animals. Students worked in the greenhouses, planted seedlings, and harvested and tasted carrots. Students had lunch at the restaurant that received some fresh produce from the farm.

3.5.4 Data Sources and Data Collection Methods

The data collected for this study consisted of various sources: background and feedback questionnaires, two Applesauce assignments before and after the sustainable food systems learning experience, two interviews before and after the learning experience, and ten worksheets. I collected data from several sources based on a pragmatist approach to provide substantial evidence to answer the research questions. Other data sources such as researcher's field notes from direct observations and conversations with the teachers were used as supplementary data sources to provide more context and further substantiate the data analysis and narrative. Next, I described the purpose and characteristics of each instrument collected in a chronological order.

First, in order to learn about the participants' background and previous experiences, a background survey questionnaire was administered before the students participated in the sustainable food systems learning experience (see Appendix C). The questionnaire explored students' demographic information (i.e., gender, grade level, race and ethnicity, and eligibility for free/reduced price meals); previous experiences (i.e., farming and gardening, agriculture and environmental studies, farm visit, food shopping, and cooking); and knowledge (i.e., sustainability). Additional questions were asked to collect quantitative data to report to the funding organization and were not part of the data analysis of this dissertation. The results for those additional questions were presented in Appendix H. All questions on the questionnaire were reviewed and approved by the panel of experts for face and content validity.

Second, students were asked to demonstrate their systems thinking and knowledge about food systems using the Applesauce assignment (see Appendix D) before starting the first lesson. The assignment consisted of three pages. The first page contained a brief definition of systems thinking, the assignment instruction, and Chase and Grubinger's (2014) complex diagram of food systems. A table was provided on the second and third page to give more structure for students to identify components and relationships between different stages of applesauce system (i.e., growing apples, processing applesauce, and consuming applesauce) and each topic in the diagram (i.e., inputs, production and distribution, human health and well-being, environmental impacts, influences, and outputs, Chase & Grubinger, 2014). After the last lesson, I asked students to complete the Applesauce assignment again to demonstrate their systems thinking and knowledge about food systems after participating in the sustainable food systems learning experience and to compare and contrast with the first one.

Third, a semi-structured 45-minute interview was conducted with each of the six students before they began the first lesson to obtain some in-depth information about their background and previous experiences as well as the explanation about their thinking in the context of sustainable food systems (see Appendix E). In preparation for the interview, I reviewed students' responses to the background questionnaire and the Applesauce assignment. I asked students to elaborate or provide examples for their responses to the questionnaire and clarify their answers on the Applesauce assignment. For example, I asked students about their experiences in cooking or choosing what to eat. In addition, I asked them to define the terms food systems and sustainability.

Fourth, for each of the 10 self-directed online lessons, students completed a worksheet (see Appendix G). To explore students' perceptions toward the instructional design features of the online lessons, students were asked to reflect on what they found useful about each lesson and what they thought could be improved for the lesson by documenting their thoughts at the bottom of each worksheet. To explore how students intended to apply systems thinking beyond the learning experience, students responded to reflective questions on the last worksheet (i.e., how would you apply systems thinking to choose what food you will buy and eat from now on? How can thinking of food as a system help you support a food system to become more sustainable?)

Fifth, in my field notes I recorded my observations in the classroom and during the field trips. I observed how students reacted toward the learning experience and comments they made. I also recorded my conversations with the teachers to gain insights of the teachers' perspectives of the students' learning experiences. I had three conversations with the classroom teacher after the third lesson, the sixth lesson, and the last lesson to get feedback regarding students' experiences, insights on the usefulness of the sustainable food systems learning experience, suggestions for future improvement, and observations on students' level of engagement (see Appendix F). In addition, I had two conversations with the mother who served as the homeschool teacher after the third lesson and the last lesson to gain some feedback regarding the student's learning experience.

Sixth, a feedback questionnaire was administered after the last lesson (see Appendix C) to explore students' overall experience toward the sustainable food systems learning experience using 12 items adapted from Purdue Instructor Course Evaluation Service Item Catalog (Poor, n.d.) and used a Likert-type scale: 1 = strongly disagree; 2 = disagree; 3 = agree; and 4 = strongly agree. In this study, the reliability coefficient using Cronbach's *alpha* was 0.80 ($N = 12$). An additional open-ended question was asked to explore how students would apply systems thinking in everyday life. Additional questions were asked to collect quantitative data to report to the funding organization and were not part of the data analysis of this dissertation. The results for those additional questions were presented in Appendix H.

Finally, the second semi-structured 45-minute interview with the same six students was conducted one week after the final lesson (see Appendix E). I revisited a few questions from the initial interview during the second interview (i.e., what does the term food systems mean in your opinion? What kind of the environmental impact is related to food systems? What does a sustainable food system look like?), along with the new questions (i.e., how would systems thinking or thinking of things as a system benefit you in the future? What would you do to help make food systems more sustainable? Why do you think that?). Additionally, participants were asked about the instructional design features of the curriculum and their overall experience in the sustainable food systems learning experience. In the end, I asked participants to talk about their intention to apply systems thinking in the future.

My field notes from classroom and field trip observations and conversations with the teachers were organized. All of the recorded interviews were transcribed and reviewed with the audio at least twice to confirm the transcription. No names, social security numbers, or other identifiers were used. All documents and records of this study were kept secure in a locked cabinet. All data that were entered into the computer were secured by a password-protected system.

Table 3.3: Data Sources and Data Collection Timeline

Research Questions	Data	Sources	Timeline	Duration
RQ1	Primary	Interview Transcripts	Before the first lesson/ After the final lesson	45 minutes each
		Applesauce Assignments	Before the first lesson/ After the final lesson	35 minutes each
RQ2	Primary	Interview Transcripts	Before the first lesson/ After the final lesson	45 minutes each
		Bottom of Worksheets	All 10 lessons	10+ class periods
		Feedback Questionnaire	After the final lesson	15 minutes
	Supplementary	Field Notes from Observations	During the lessons	~15 hours
		Field Notes from Conversations with Teachers	After the third, sixth, and last lessons	30 minutes each
RQ3	Primary	Interview Transcripts	Before the first lesson/ After the final lesson	45 minutes each
		Feedback Questionnaire	After the final lesson	15 minutes
		Worksheet	The last lesson	2 class periods

3.6 Data Analysis

Guided by a pragmatist paradigm, I synthesized the existing literature regarding systems thinking definitions and sets of systems thinking abilities (e.g., Ben-Zvi Assaraf & Orion, 2010b; Meadows, 2008; Meilinda et al., 2018; Ponto & Linder, 2011; Valerdi & Rouse, 2010) and developed an analytical framework for this study (Figure 3.1). The analytical framework helped me organize the codebook after open coding for the first research question that sought to describe the demonstration of systems thinking and the third research question for the application of systems thinking.

First, the definition of systems thinking is a mode of thinking that sees a system as a whole and how parts interact with one another rather than focusing on a single part (Bartlett, 2001; Kasser, 2018). Based on this definition, the analysis for how students demonstrated systems thinking made a distinction between how students demonstrated an understanding of a whole with various interactions of processes and components (Ben-Zvi Assaraf & Orion, 2010b;

Meilinda et al., 2018; Valerdi & Rouse, 2010) and how students focused on separate parts which is reductionistic (Valerdi & Rouse, 2010; Verschuren, 2001). Unlike the existing literature, the analytical framework developed for this study did not focus on students' abilities to identify components and processes as addressed in Ben-Zvi Assaraf and Orion (2010b) and Meilinda et al.'s (2018) models because, by breaking a system into separate parts, they are reductionistic in nature (Valerdi & Rouse, 2010; Verschuren, 2001) instead of being holistic.

Second, systems thinking expected an individual to understand nature and behaviors of a system (Ben-Zvi Assaraf & Orion, 2010b; Meadows, 2008; Valerdi & Rouse, 2010). The analysis was based on how students recognized and understood that a system is complex, dynamic, nonlinear, and cyclic (Meadows, 2008; Ponto & Linder, 2011; Valerdi & Rouse, 2010) and can be affected by delays, feedback loops, buffer, and leverage points at multiple scales (Meadows, 2008; Meilinda et al., 2018; Ponto & Linder, 2011).

Third, a system thinker is expected to view a system from multiple perspectives, in temporal dimension, and in spatial dimension (Lee et al., 2017). The analysis was based on how students used different perspectives to view a system and how they considered time and place related to their understanding of a system (Ben-Zvi Assaraf & Orion, 2010b; Meilinda et al., 2018; Ponto & Linder, 2011; Valerdi & Rouse, 2010).

Finally, applications of systems thinking were explored based on the two main goals of systems thinking: (1) to help an individual better understand complex phenomena (Ponto & Linder, 2011); and (2) to support an individual in making decisions to change a system to be more desirable and sustainable (Arnold & Wade, 2015; Bawden, 1991; Ponto & Linder, 2011). Therefore, the data analysis was based on how students applied systems thinking by discussing about complex phenomena and how they applied systems thinking by discussing about their thoughts or their intentions to take an action that would lead to a more desirable and sustainable system.

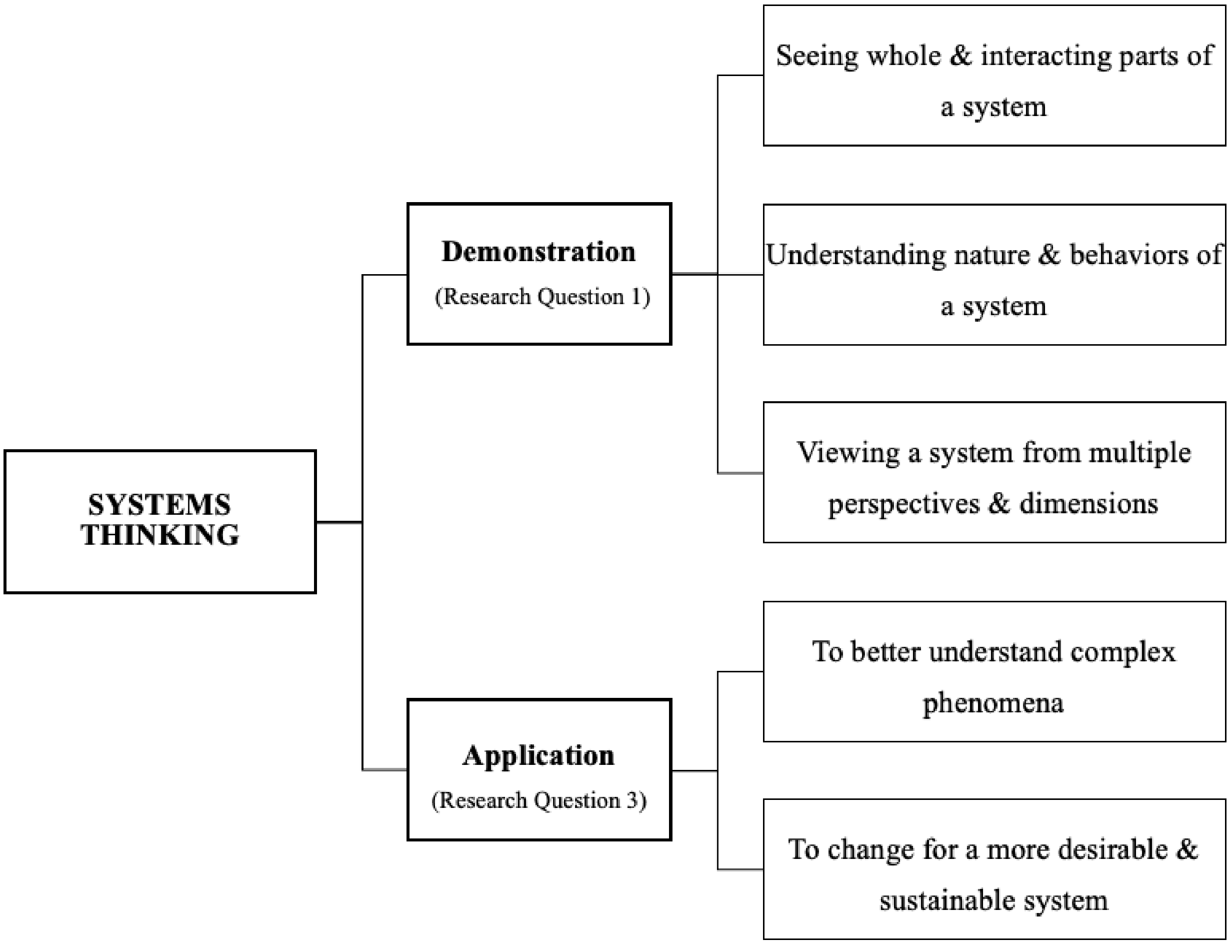

Figure 3.1: Analytical Framework for the Study

Different data analysis methods were used to analyze each data source (see Table 3.4). My decisions to choose the analysis methods were informed by pragmatist assumptions in selecting a practical strategy for each research question with available resources and timeframe and I provided the rationale for my decisions. Coding strategies guided by the review of literature were used to analyze the textual data. Descriptive statistics was used to analyze numeric data. All textual data including Applesauce assignments, interview transcripts, worksheets, and field notes were first read line by line to enhance familiarity with the data. I highlighted the data for students' background and previous experiences and for each research question using different colors. I also took notes for later analytic consideration. The analytic approach involved a detailed description of the case and the setting of the case within contextual conditions (Creswell et al., 2007).

Table 3.4: Data Analysis Methods

Research Questions (RQ)	**Data Sources**	**Analysis Methods**
RQ1: In what ways did students demonstrate systems thinking throughout the sustainable food systems learning experience?	Interview Transcripts	First Cycle: Concept and Process Coding Second Cycle: Pattern Coding
	Applesauce Assignments	
RQ2: How did the instructional design of this learning experience help students learn about, engage in, and practice systems thinking?	Interview Transcripts	First Cycle: Descriptive and *In Vivo* Coding Second Cycle: Pattern Coding
	Bottom of Worksheets	
	Evaluation on Feedback Questionnaire	Descriptive Statistics
RQ3: How did students intend to apply systems thinking beyond the learning experience?	Interview Transcripts	First Cycle: Descriptive Coding Second Cycle: Pattern Coding
	Open-Ended Question on Feedback Questionnaire	
	The Last Worksheet	

First, I focused on describing the contextual conditions using the background survey questionnaire and interview transcripts. Descriptive statistics was used to analyze frequencies regarding students' previous experiences (i.e., farming and gardening, agriculture and environmental studies, farm visit, food shopping, and cooking) and knowledge (i.e., sustainability) with the Statistical Package of the Social Scientist (SPSS) Version 25. I read the interview transcripts, highlighted phrases and words regarding student's previous experiences related to food systems and sustainability, and wrote a summary for each student. Students' background and experiences related to food systems before the sustainable food systems learning experience were reported as tables and narratives to present the contextual conditions and to develop the feel of context (Stake, 1995).

For research question 1, *"In what ways did students demonstrate systems thinking throughout the sustainable food systems learning experience?"* The interview transcripts and Applesauce assignments were used as data sources. The interview transcripts provided most information and therefore, drove the analysis. For the first cycle coding, I coded the interview transcripts first, followed by the interviewees' Applesauce assignments. Then, I recoded the interview transcripts to generate a codebook and triangulated the data. Concept and process coding strategies were used to translate data and interpret meanings of each datum (Saldaña, 2016). I used concept coding strategy to help me identify concepts related to systems thinking that students demonstrated. I used process coding strategy to help me capture students' actions during the interview that indicated how they demonstrated systems thinking. The second cycle of coding was completed using pattern coding to group those coded data into categories or themes (Saldaña, 2016). I looked for common themes, and interpreted the findings in terms of the case as a whole to help readers understand the complexity of the case (Stake, 1995). After analyzing data from the six students in the sample, I analyzed the Applesauce assignments from students who were not interviewed.

For research question 2, *"How did the instructional design of this learning experience help students learn about, engage in, and practice systems thinking?"* The interview transcripts, the bottom of the worksheets, and the feedback questionnaire were used as primary data sources. The interview transcripts provided most information and therefore, drove the analysis. For the first cycle coding, I coded the interview transcripts first, followed by the interviewees' responses in the bottom of the worksheets. Then, I recoded the interview transcripts to generate a codebook and triangulated the data. Descriptive and *In Vivo* coding strategies were used to translate data and interpret meanings of each datum (Saldaña, 2016). I used descriptive coding strategy to summarize students' experiences in a word or a short phrase. I used *In Vivo* coding strategy to highlight the students' voice toward the learning experience. The second cycle of coding was completed using pattern coding to group those coded data into categories or themes (Saldaña, 2016). After analyzing data from the six students in the sample, I analyzed the worksheet responses from students who were not interviewed. In addition, field notes from my observations and conversations with the teachers were used as supplementary data source to further substantiate the narrative. For numeric data on the feedback questionnaire, descriptive statistics was used to analyze frequencies with the Statistical Package of the Social Scientist (SPSS) Version 25 to describe students' perceptions toward the overall experience.

For research question 3, *"How did students intend to apply systems thinking beyond the learning experience?"* The interview transcripts, worksheets of the last lesson, and an open-ended question on the feedback questionnaire were used as data sources. The interview transcripts provided most information and therefore, drove the analysis. For the first cycle coding, I coded the interview transcripts first, followed by the interviewees' responses to worksheets and questionnaire. Then, I recoded the interview transcripts to generate a codebook and triangulated the data. Descriptive coding strategy was used to translate data and interpret meanings of each datum (Saldaña, 2016). The second cycle of coding was completed using pattern coding to group those coded data into categories or themes (Saldaña, 2016). After analyzing data from the six students in the sample, I analyzed the worksheets and questionnaire from students who were not interviewed.

The findings were written as a detailed description to answer each research question about students' demonstration of systems thinking in the sustainable food systems context, students' perceptions toward the instructional design features of the learning experience, and students' intention to apply systems thinking. I interpreted the unusual situations to help answer the research question then reported lessons learned from the case (Creswell et al., 2007).

Table 3.5: Examples of Codes

RQ	Categories	Definitions	Open Codes	Examples
1	Describing a system	Students gave an explanation about a system and its complexity and showing a connection of different relationships within or between the system.	• Whole	“everything is really connected to everything else. It’s really hard to isolate a certain thing, or a certain—anything into just one part.”
			• Connection	“see how it connects to different places and different things and how it affects the things around it.”
			• Consequence	“the environment has an effect on foods and food also has an effect on the environment.”
	Understanding a system	Students recognized nature, behaviors, or characteristics of a system which is always changing and is influenced by or influencing other parts of the system.	• Cyclic	“once the food's disposed, it decomposes and then that decomposes used to help the plants grow and it's, there's really no end.”
			• Changeable	“we have a lot of technological improvements or discoveries that help us. It’s really affecting the way of what we eat and what we choose to buy at the store”
			• Feedback	“if a lot of people like applesauce, then there’s obviously gonna be more companies making applesauce. But if people stop buying applesauce because they don’t like it, then the applesauce business will go bankrupt.”
	Viewing a system	Students used multiple perspectives as well as using the concept of place and time to consider a system.	• Perspectives	“but someone else with other viewpoints can obviously see it as something else differently.”
			• Spatial dimension	“where she buys, it comes from different places”
			• Temporal dimension	“it was farming in the past but it greatly affected their present because they were experiencing dust and dust storm everywhere all the time”

Table 3.5 continued

RQ	Categories	Definitions	Open Codes	Examples
2	Applesauce assignment	Students talked about their experiences and perceptions toward the Applesauce assignments.	• Structure • Time-related • Thinking • Context	"I think it's not easy because easy would be just 'here's the information, memorize the information and write down the information.'"
	Online lessons and worksheets	Students talked about their experiences and perceptions toward the lessons and worksheets.	• Format • Self-learning • Examples • Organization	"I don't do well with online sites. I would rather have the paper and do notes on, like written notes in class."
	Experiential learning activities	Students talked about their experiences and perceptions toward the experiential learning.	• Guest speakers • Field trips • Content knowledge • Activities	"I've never actually had to do something about it or go and see what we were learning about and it makes you think a lot more and I really liked it."
3	Understanding complex phenomena	Student discussed about their thoughts on complex situations or phenomenon	• Looking at a phenomenon • Seeing things differently • Performing a task • Increasing effectiveness/efficiency	"If you have a good understanding about all this, you can understand other things that start with this. [You can] research further the improvement of the environment."
	Changing for a desirable and sustainable system	Students discussed about a change for the better that they already did or they intended to do.	• Making a food-related decision • Better environment • Supporting community • Healthier	"If we encourage more people to buy healthy foods, that would really help the environment and not much food would have to be processed and packaged."

3.7 Trustworthiness of the Study

In qualitative research, there are four major concerns in relation to trustworthiness. Those concerns are credibility, transferability, dependability, and confirmability (Guba, 1981; Lincoln & Guba, 1985; Shenton, 2004). These concerns were addressed in the research design and data analysis as followed.

Credibility of the findings and interpretations were tested using various data sources including prolonged engagement, member checking, and triangulation (Guba, 1981; Lincoln & Guba, 1985). Prolonged engagement in this study included field notes over the period of nine weeks from the first day I met the class to the last day I interviewed the participants. I spent approximately 15 hours with the participants in this study during the class periods and two field trips. For member checking, I restated or summarized the interviewees' responses and then questioned them to determine accuracy during the interviews, which gave them the opportunities to make appropriate corrections. Triangulation is a procedure of using multiple perceptions to clarify meaning or identify different ways to view the phenomenon (Stake, 2003). The data were collected and analyzed from multiple sources such as questionnaires, interviews, field notes, assignments, and worksheets.

Some transferability between two contexts is possible depending on the similarities between them (Guba, 1981; Lincoln & Guba, 1985). Thick descriptions demonstrated the degree of similarity between different contexts to suppose that tentative findings in one context could likely hold in another (Guba, 1981; Shenton, 2004). Although the readers were the one making a decision to apply this study to their particular situation, as the researcher, I had an obligation to provide enough details of the context to enable that comparison (Merriam & Tisdell, 2016).

Dependability refers to the concern over the stability of the data due to the possibilities of instrumental shifts (Guba, 1981; Lincoln & Guba, 1985). As qualitative researchers believe in multiple realities and using humans as instruments, the instruments can be changed due to "evolving insights and sensitivities" (Guba, 1981, p. 81). I documented the rationale and subsequent execution of all phases of the study in the forms of field notes to demonstrate the "explainable changes in instrumentation" (Guba, 1981, p. 81). The documentation was examined by my graduate advising committee members to make sure that the procedures fell within generally accepted practice (Guba, 1981).

Confirmability focuses on screening out the researcher's biases (Guba, 1981; Lincoln & Guba, 1985). Triangulation, as discussed earlier, used multiple sources of data for cross-checking through worksheets and follow-up interview with the same students (Merriam & Tisdell, 2016). As Guba (1981) recommended, I provided at least two sources of documentation for every claim. In addition, discussing about my positionality as a researcher was a self-reflection about worldview, assumption, biases, and relationship to the study that also revealed my underlying epistemological assumptions that guided my role in this study to the readers (Guba, 1981; Merriam & Tisdell, 2016).

Finally, the trustworthiness of the study depended upon the ethics of the researcher (Merriam & Tisdell, 2016). As I was a "guest" to the study participants, I practiced good manners and followed code of ethics (Stake, 2003). Most importantly, the Institutional Review Board approved this study protocol (see Appendix A). Students and their parents provided written informed assent and consent to participate in this study (see Appendix B).

3.8 Limitations

Despite several attempts I made to ensure the trustworthiness of this study, being aware of limitations was necessary when reviewing the findings. First, although I visited the classroom and tried to build rapport with the students, there was no guarantee that they would feel comfortable or willing to share their honest thoughts and perceptions with me as an outsider whether in their questionnaires, worksheets, or interviews. Second, the students participated in this learning experience as part of their food science class or agriculture/engineering class. There were possibilities that students would complete the assignments without putting a lot of effort in order to meet the requirements. Third, my value in the concept of holism and my role as the person who developed the learning experience might lead to preconceived assumptions. I structured the interview process in a way that minimized leading questions. Finally, this study was conducted by one individual in a limited time frame of six weeks. It did not allow for more prolonged engagement or multiple perspectives from another researcher.

CHAPTER 4: FINDINGS

4.1 Chapter Overview

This chapter presents the findings from the qualitative case study. In an effort to understand high school students' systems thinking in the context of sustainable food systems, findings were presented in four sections. These sections contributed to the understanding of the context of the case and addressed the three research questions. The first section, *Students' Background and Previous Experiences*, described students' knowledge and exposure to the sustainable food systems topic before participating in the sustainable food systems learning experience. The second section, *Students' Demonstration of Systems Thinking*, highlighted how students demonstrated abilities and levels of systems thinking in the context of sustainable food systems throughout the learning experience. The third section, *Instructional Design for Systems Thinking*, described students' perceptions and experiences toward the instructional design features of the learning experience that helped or hindered them in practicing and learning systems thinking in the context of sustainable food systems. Finally, the fourth section, *Applications and Benefits of Systems Thinking*, reported how students explained the benefits of systems thinking and their intentions to apply systems thinking beyond the learning experience.

4.2 Purpose of the Study

The purpose of this study was to explore and describe high school students' systems thinking throughout a sustainable food systems learning experience, which was designed for students to practice systems thinking. Further, the researcher sought to explore how the learning experience helped students practice systems thinking and how students intended to use systems thinking beyond the learning experience.

4.3 Research Questions

Three research questions guided this study:

1. In what ways did students demonstrate systems thinking throughout the sustainable food systems learning experience?
2. How did the instructional design of this learning experience help students learn about, engage in, and practice systems thinking?
3. How did students intend to apply systems thinking beyond the learning experience?

4.4 Students' Background and Previous Experiences

This section focused on reporting participants' background and prior experiences related to food systems and sustainability to describe the context of the case. Prior to the sustainable food systems learning experience, all participants responded to the pretest questionnaire. The summary of their background and previous experiences that were relevant to food systems and sustainability was presented in Table 4.1.

Table 4.1: Background and Previous Experiences of Study Participants

Pseudonym	Learning Agriculture/ Environmental Topics Outside of School	Visiting a Farm and a Farmers' Market	Shopping for Food and Cooking	Farm or Garden Experiences	Defining Sustainability
Apricot	Infrequent	Infrequent	Frequent	Garden	N/A
Arugula	Frequent	Infrequent	Frequent	Neither	N/A
Blueberry	Infrequent	Infrequent	Frequent	Neither	"Something that is kept stable."
Edamame	Frequent	Frequent	Frequent	Neither	"To maintain."
Ginger	Frequent	Frequent	Frequent	Neither	"Produce food."
Jalapeño	Infrequent	Infrequent	Frequent	Neither	"Something that we are able to keep growing and not run out of."
Jujube	Frequent	Frequent	Frequent	Garden	"To be able to sustain something."
Kale	Frequent	Frequent	Frequent	Neither	N/A
Kiwi	Frequent	Frequent	Frequent	Farm	N/A
Nectarine	Frequent	Infrequent	Infrequent	Garden	"The practices that will benefit whatever the practices are applied to both in the short term and in the long term."
Raspberry	Frequent	Infrequent	Frequent	Garden	N/A
Spinach	Frequent	Frequent	Frequent	Farm	"The ability to produce food."

All 12 study participants represented a wide range of background and experiences. Most students were familiar with purchasing and cooking food, some students were familiar with agriculture, and few students were familiar with environmental and sustainability topics. In addition to the questionnaire, six students were interviewed for more details of their background and experiences related to agriculture, food, environment, and sustainability.

From the interviews, two students had a much higher exposure to agriculture than their peers. Kiwi grew up on a large farm raising livestock, growing crops, and using farming equipment. He was involved in FFA and 4-H animal-related activities. Kiwi herded livestock to the Western Midwest every year and noticed changes in the weather patterns, which would be discussed in another section. His extended family shared meat from the animals they raised and sold the surplus to a local market. Correspondingly, Nectarine grew up on a small fruit farm and orchard. He also participated in 4-H agriculture-related projects including forestry and water conservation. In addition, he did some research regarding free trade and environmental sustainability as part of his participation in a debate club.

The interviews also showed that two students had a moderate exposure to agriculture. Raspberry took several classes in food and animal science. She had a small vegetable garden and had experiences in growing and preserving produce. Similarly, Jujube took several agriculture classes since her freshman year. Her parent was professionally working with soil and plants and her career goal was to work with animals. Two students had a limited exposure to agriculture. Apricot's family had a small "improvised garden" that she was occasionally involved in. Blueberry visited a farm once in middle school but he could not remember the details.

In terms of cooking, all participants but one cooked for themselves regularly. From the interviews, Blueberry had a cooking job at a chain restaurant while Apricot and Raspberry aspired culinary careers. In terms of food decisions, some interviewees purchased ingredients from supermarkets while some purchased from smaller markets and co-ops. Two-thirds of the interviewees identified cheaper price as one of the factors in making food purchase decision, preferred minimally processed foods, and had a healthful diet. In order to demonstrate various factors that influenced interviewees' food choices, examples were provided as followed.

Raspberry prioritized eating a lot of fruits and vegetables. She elaborated:

> Mainly because [fruits and vegetables] give us different vitamins and nutrition. And different vitamins like A and B and C, depending on what you're looking for, because it helps not only your body and your sores, but it helps boost up your energy as well…. Mainly, I'm not all, like, oh for my health. But most of the food I select is pretty healthy in general anyway. It's kind of both in a way.

Raspberry learned about processes behind one of her favorite foods. She felt disgusted by what she learned and stop liking the food item. She shared:

> I used to love hotdogs like crazy. And then my teacher in middle school showed us the video of how hotdogs are made…. I stopped liking hotdogs and then I figured out what was in hotdog and how they were made and I was like 'Nope. No more.' It's kind of disgusting of how they make it.

Apricot also discussed about her food restriction dictating her food decisions. She explained that artificial ingredients could make her feel sick, so she avoided them. She said:

> I'm fructose intolerant so I can't have anything with artificial sugars like high fructose corn syrup. So, everything that I pick, like for ketchup, I have to read all the labels. If there's stuff I can't pronounce, we're probably not going to get it. We pick healthy foods coz we are allergic to everything else…. Just like chocolates, you know, if you go to the store and they have like the row of chocolates, it's kind of nasty coz I'm like allergic to all of it. So, it just makes me throw up. So, I just take the healthy foods instead.

Later, Apricot also discussed about her thinking of her health and food passage through her body influencing her food choices. She shared:

> I really focus on my health a lot. So, I focus on what I put in my body…. I know that what I put in my body has to go through my body and it has to come from somewhere. So, I focus on where things come from in a store and what I am putting in my body.

Like Apricot, Nectarine thought about where food came from. His definition of healthy diet consisted of organic food and limited chemicals used in food production. He stated:

> I would try to eat healthy. Healthy is organic or hopefully, at least limited chemicals…. Certified organic is one thing but if you have something like an orange or avocado, because of the thick outer shell, you could maybe buy something that's not organic because the chemicals are not going to be inside where you actually eat. But for an apple where you eat basically everything, you try to buy organic because all the chemicals that are on there are going to go into your body and kind of take care of your body.

In summary, these examples showed that the interviewees perceived healthful foods to be foods that nourish the body, do not trigger allergic reaction, and do not contain harmful chemicals. On the other hand, Kiwi did not perceive his diet to be healthful. Although routinely Kiwi ate meat with potatoes, peas, green beans, or corns, he said he did not eat any other vegetables to be considered having a healthy diet. Healthful food for Kiwi meant a lot of vegetables and he stated that he was not interested in changing this routine.

In terms of defining sustainability, Blueberry's definition was "[Practices that are] not changing. You're killing animal the same way and you're consuming the food the same way. And you're not changing the company that you're buying from. You're just staying consistent with the way you do things." Kiwi associated the term sustainability with "the amount of rain and sunlight without drought coz it will increase the quantity of the plants" but he could not define the term. Nectarine was in a debate club that required him to research values of environmental sustainability. His definition of sustainability included the well-being of the environment and the consideration of both short-term and long-term effects of any specific practices. More specifically, Nectarine discussed about biodiversity and environmental stewardship through defining sustainable food systems as followed:

> The examples [of sustainability] would be the way you grow the products. You try to not spray too many pesticides so that you're not killing all the soil and you're not spraying herbicides and killing all the plants everywhere. Monoculture, which is what we're doing in Indiana, isn't that great either. Because if you have something that affects corn, all the corns are gonna die. And there is nothing stopping it from just spraying it like crazy. But if you have a little bit of everything, the disease outbreak would be more isolated. So, thinking about things like that and just trying to develop practices that fit the environment and fit the climate. That will also help to not destroy what you're using. Like not just using up resources just because they're available, but actually try to use them in a responsible way. Preserve them.

Additionally, some interviewees shared their background regarding food systems and discussed the values of systems thinking. For example, Apricot watched several documentaries called *How It's Made* and learned about how foods were raised, made in a factory, and sent to the store. She wanted to be a chef and saw a value in knowing the science behind her ingredients, which could affect her outcome. More importantly, she stated that knowledge is power and it was beneficial to think about food as a system. She said:

> You get a new understanding. It's good for you. You start thinking about other things that's not just food, you know. Things that happen. You'll know that you're not the only person. So, you have to think about other people and other things of where thing starts. Just getting a new perspective on thing is beneficial. You understand things a lot better than other people do. Knowledge is power.

Nectarine learned about food from reading homestead magazines and growing up in a family that used whole foods, such as grinding organic wheat berries from a bulk bag to make pancake flour.

He discussed about highly processed foods that urged people to keep consuming, which threw the body off balance. He said:

> I mean people can just eat sugar and their bodies don't tell them to stop. If you eat honey after a while, your body is going to be like, 'You've had enough honey.' And honey is a sweetener too. But with sugar because it's so highly processed, it's just empty. So, you taste it but you never get full of it. So that throws off the balance of your body. So that's not being smarter with what you're eating. It's not being healthy.

More importantly, Nectarine discussed about a fundamental idea of systems thinking. He stated that everything is connected to everything else. He explained:

> Anything that you interact with in your life is probably going to be pulled to different parts of your life just because you're interacting with both things. So, I think all systems are intrinsically connected.… The food system—food is grown in our environment. And the environment affects everything we do. You can make the connection to all of your life to the environment. And so, food systems are connected to us on a bigger level, connected to more things.

In contrast, Blueberry, who wanted to pursue a weight training career, only expressed interest in nutrition aspect of food. He thought that other aspects in food systems were irrelevant and might be useful only in determining which brands offered healthier products. In addition, he pointed out that he was not concerned about other people's opinions if they argued about something he did not care about. This is contrary to the expectation that a systems thinker should value multiple perspectives.

To sum up, this section presented participants' diverse background and prior experiences related to sustainable food systems. Students' knowledge, experiences, and interests regarding food, agriculture, and environmental and sustainability topics as well as thoughts related to systems thinking were discussed to provide context for the case study.

4.5 Students' Demonstration of Systems Thinking

This section addressed the first research question by describing how students in the case study demonstrated systems thinking throughout the sustainable food systems learning experience. After analyzing all the data sources, I concluded that the six students, who were interviewed, provided substantial data to describe this research question. Therefore, this section mainly reported the analysis of the six interviewees as two groups: (1) a group of interviewees who demonstrated systems thinking, which consisted of Nectarine, Apricot, and Jujube; and (2) a group of interviewees who did not demonstrate systems thinking, which consisted of Kiwi, Blueberry, and Raspberry. These two groups were divided based on the evidence from data analysis using the analytical framework (see Figure 3.1). Guided by the themes from the coding processes, the findings were reported based on systems thinking abilities of how students described a system, showed their understanding of a system, and viewed a system. An overview of the emergent characteristics of each systems thinking ability described in the following sections was presented in Table 4.2.

Table 4.2: Summary of Characteristics of Systems Thinking Abilities

Systems Thinking Abilities	**Emergent Characteristics**
Describing a system	• Demonstrating a system's complexity • Demonstrating a system's wholeness • Showing a web of connections or relationships • Connecting a system with other systems
Understanding nature and behaviors of a system	• Understanding a system's changeability • Understanding a system's cyclic nature • Understanding a system's feedback loops

Viewing a system	• Using multiple perspectives
	    • Multiple disciplines
	    • Other people's viewpoints
	• Using spatial dimension
	• Using temporal dimension

4.5.1 Describing a System

Based on the definition of systems thinking, a systems thinker was expected to see a system as a whole (Bartlett, 2001) and see various interactions of processes and components within the system and with other systems (Ben-Zvi Assaraf & Orion, 2010b; Meilinda et al., 2018; Valerdi & Rouse, 2010). There was a distinction between how the two groups of interviewees explained about a food system and how they made connections between various parts within the food system and between a food system and other systems during the interviews and on the Applesauce assignments. Students, who explained about connections or interactions between various parts, components, and processes as well as not saw a part of a system as a separate entity, were considered demonstrating systems thinking. They demonstrated that they understood about a systems' complexity, wholeness, and a web of connections as well as connected a system with other systems. I reported this section as two subsections focusing on: (1) connections within a food system; and (2) connections between a food system and other systems.

4.5.1.1 Connections Within a Food System

In this subsection, I described how students defined a food system during the interviews to show what they thought a system was and how they saw connections between parts within the system. In addition to the interviews, Applesauce assignments were crucial in demonstrating specific relationships within a food system that students made in terms of inputs, food production and distribution, influences, and outputs for the three processes: growing apples, processing applesauce, and consuming applesauce (see Appendix D). I started by describing how Nectarine, Apricot, and Jujube discussed about the complexity of a food system and connections between parts of the food system.

During the pretest interview, Nectarine discussed about why he thought that a food system was a complex system. First, he discussed about the difficulty of dividing a system into a single part, which meant he saw a system as a *whole* instead of separate parts. Moreover, he made *a web of connections* between various components and processes related to a food system to explain the *complexity* by discussing about inputs (e.g., fuel for the truck and the factories, labor to drive and operate machinery, food to feed those workers), outputs (e.g., emission caused by transportation and food processing), and influences (e.g., other people influencing on those workers). In addition, he identified the indirect influence on the entire system. He shared:

> I think that everything is really connected to everything else. It's really hard to isolate a certain thing, or anything into just one part…. I'm just thinking about how the trucks that are transporting of the apples everywhere are causing emissions. And I'm thinking the factories cause emissions, how we have to have fuel to run the factories, and fuel to run the trucks, and how people have to run all the machines. And then, those people have to be fed. And then you can even go further into the people. And people affect how people are gonna work and you can really just keep going back and back even though that's not the system, it's affecting the people that are affecting the system. Therefore, indirectly affecting the system.

During the posttest interview, Nectarine summarized how systems thinking helped him see a system as a whole, which demonstrated that he understood the concept of a web of connections constituting a complex unity. He said:

> I can a little bit better be able to see a bigger picture. Like, just see the bigger picture, you know, not just like here's this, but see how it connects to different places and different things and how it affects the things around it.

Nectarine also provided lengthy responses on the Applesauce assignments both pre- and posttest, which demonstrated his ability to make various connections and see parts interacting with each other in a system. He made at least two connections for each topic. Collectively, his responses demonstrated diverse connections he made while describing a system. For example, his responses regarding growing apples in the pretest Applesauce assignment were as followed:

> <u>Inputs</u>: The money that was required to buy the trees, any pesticides, or fertilizers; time spent pruning the trees; energy that was used in planting (fossil fuels); people monitoring growth; pollination by insects or wind; environment may be unfavorite to growth; irrigation.
>
> <u>Production and Distribution</u>: Trees coming from somewhere; people to plant the trees.
>
> <u>Influences</u>: Past planting practices influence how trees are planted and cared for; the beliefs of the farmer may affect how the plants are cared for; climate may determine whether apples may or may not be grown.
>
> <u>Outputs</u>: Oxygen produced by trees; bees may make honey; bad apples, good apples.

On the posttest Applesauce assignment, Nectarine used categories on the provided diagram to guide how he made connections. Some responses were similar to the pretest assignment and some were new. The following examples were also from growing apples section for a comparison. He wrote:

> <u>Inputs</u>: Fossil energy—transporting trees to plant, powering tractors for harvesting; knowledge—how to prune trees, how to be an organic farm; natural resources—fertilizers; labor—doing farm chores.
>
> <u>Production and Distribution</u>: Transportation—transporting fertilizers and labor to the farm; packaging—the trees and fertilizer will be packaged.

> Influences: Research—different breeds of apple trees may affect what trees are planted. Modern machines may influence how apples are harvested; climate—climate will dictate what kind of trees may be planted.
>
> Outputs: Food products—apple trees will produce apples; economic activity—more or less apples will dictate the price of apples.

Apricot was another interviewee who was able to explain why she thought that a food system was a *complex* system. During the pretest interview, Apricot mentioned that there was "a lot that happens" in a food system, which she addressed that "it's complex for every single food." After the learning experience, she specified about different processes (e.g., growing lettuce, traveling to a store, inventory, refrigeration); inputs (e.g., electric to open garage door, gas for cars to get to the store, labor to stock shelf, truck for transportation); and outputs (e.g., waste that goes into toilet). She addressed that the different parts contributed to a food system being *whole*. She said:

> Food system is huge and that's something that people don't understand. If you're going to go to the store and get lettuce, there had to be someone—there's gotta be a truck that brought it to the store and an employee that put it on the shelf. And then you had to, you know, use electric or whatever to open your garage door and gas to get to the store. And also growing it. There had to be a farmer. And afterwards, once you eat it, or sorry, you take it home, put it in the fridge and then after you eat it, it goes in the toilet. And then so food system, oh, food system is like the whole, it's huge. I never realized how big it was.

Apricot also demonstrated the ability to make various connections on the Applesauce assignments both pre- and posttest by identifying categories on each table cell. However, Apricot did not provide a lengthy explanation for all her responses. She later admitted to me that she was tired of filling out the table cells. Her responses regarding growing apples on the pretest Applesauce assignment were as followed:

> Inputs: Knowledge—need to know how to grow it without killing it; labor—the manpower it takes to keep the orchard going; natural resources—seed, water; solar energy—the tree needs sun.
>
> Production and Distribution: Packaging—package the apple and the graft for the tree; storage—keep the tree safe and the apple; transportation—transport the tree graft.

> Influences: Weather/climate; good for research of different sorts; values—Adam & Eve.
>
> Outputs: Wood.

On the posttest Applesauce assignment, Apricot provided a few new responses with less explanation. The following examples were also from growing apples section for a comparison. She wrote:

> Inputs: Natural resources—sun, water, poop; solar energy—plants need sun; information—we need to know what we are doing.
>
> Production and Distribution: Agricultural production.
>
> Influences: Weather/climate; research; the growth of the apples depend on the weather.
>
> Outputs: Compost from using the nutrients in the soil.

The *web of connections* that Apricot made was more descriptive during the interviews than on the Applesauce assignments. Therefore, interviewees gave rigid evidence to support how they demonstrated systems thinking.

In the pretest interview, Jujube told me that a food system was "maybe what we eat or what other animals eat and the nutritional value of it." She also recognized that a food system was a complex system, but the details were unknown for her. She said:

> Not knowing the very tiny details of what goes in the applesauce makes it challenging. But just knowing that [applesauce] comes from apples and then apples are then mushed up into a sauce sort of help. But the more you look into it, there're other factors of it. Like the tools they use or the machine they use to make applesauce…. It could be much more different than what we think.

After the learning experience, Jujube learned more about food systems and demonstrated more systems thinking abilities by discussing about specific examples of the *complexity* and making connections of activities (e.g., food production, consumption, and post-consumption), locations, practices, quantity with the environmental impact. She said:

> The food system, I thought it was simpler before this lesson started. But the more we progress through the lessons and everything, I realize how complex it gets. There're so many components with the food system and that it's not just like grow, produce, wash, and then send it off to markets. So, there's a lot more than just

> that. Example would be like, where the food comes from and then how it's consumed and then what happens after you consume it and what that does to the environment. And then also just picking the amounts of food that you pick and that affects the environment.

Jujube's responses to pretest Applesauce assignment was not exemplary. She made limited connections in each table cell. Her responses described events in a food system using a few interacting components. In the growing apples section, she wrote:

> Inputs: The apple seeds are planted into the ground and water it.
>
> Production and Distribution: The farmers get seeds from the apple and plant them.
>
> Influences: Growing apples can be good for animals and can be used for other things.
>
> Outputs: Can help the soil become richer.

She also made limited connections and explanations in each table cell on the posttest Applesauce assignment. In the growing apples section, she wrote:

> Inputs: Apple seeds, soil, water, fertilizer.
>
> Production and Distribution: Farmers receive the apple seeds from stores.
>
> Influences: Promotes a healthy diet.
>
> Outputs: You receive apples.

In terms of *a web of connections* within a system, Jujube did not demonstrate this ability extensively. She might need more structure in order to express her ability in this aspect while describing a system. Nevertheless, she extensively demonstrated systems thinking abilities by describing various relationships between systems (see subsection 4.5.1.2), understanding nature, behaviors, and characteristics of a system (see section 4.5.2), and viewing a system using the concept of place and time (see section 4.5.3). Therefore, I considered Jujube to have some level of systems thinking.

Other three interviewees, Kiwi, Blueberry, and Raspberry, did not describe a system in the way that was expected of a systems thinker because (1) they did not demonstrate their understanding of complexity; and (2) when discussing about a food system, they addressed simple interactions and used limited components. For Kiwi, he said that a food system was a complex system. However, he did not provide detailed explanation regarding his understanding of the complexity. He said, “It’s kind of like the animal system, I guess. It starts off as one thing but it can be affected by many others and it just gets complicated until it’s done or restart again.”

During the pretest interview, Kiwi said that a food system is “the way it’s been brought up, to the way it’s been harvest. What happens to it in between. Seed, the plant, to it being harvested. [Food system stops] when we eat.” During the posttest interview, Kiwi expanded a food system to include post-consumption, which showed that he started to see a food system in a whole picture. He said “[Food system is] the way it's processed to the consumer to what happens after you use it.”

Kiwi completed only half of the pretest Applesauce assignment and provided limited components with limited explanations on the posttest. For example, in the growing apples section of the posttest assignment, he wrote:

> <u>Inputs</u>: Greenhouse—keeping climate controlled.
>
> <u>Production and Distribution</u>: Grown locally; keeps it grown in the same area.
>
> <u>Influences</u>: Beliefs; weather/climate.
>
> <u>Outputs</u>: Food products.

Kiwi had the potential to become a novice systems thinker. However, he still struggled to demonstrate the ability to make a web of connections, explain about systems complexity, and other systems thinking abilities based on the analytical framework. More details about Kiwi were provided in the following sections (see section 4.5.2 and 4.5.3).

For Blueberry, during the pretest interview he said that a food system is not a complex system. He said, “If you have the education and you understand where the food is coming from, people would have a better understanding of [what] that would be. It’s not complex if you have the understanding of it.” After the learning experience, Blueberry changed his mind and thought that a food system was a complex system. He did not demonstrate his understanding of the complexity. However, he included more details when explaining about a food system, including packaging company that he did not include in the pretest interview. This could be interpreted that he gained knowledge about a food system, but he still did not demonstrate systems thinking.

Blueberry also viewed post-consumption as being separate from a food system, which showed that he did not see the whole picture. He said a food system is “the process to get it to the consumer from it growing from a seed to being in your stomach." Blueberry's understanding of connections was that different processes were connected by "going from one place to the other place." When Blueberry was asked to describe a food system, he explained it in a step-by-step manner, which aligned with his understanding of how things were connected, which was linear rather than being a web of connections. The following quote showed one of the examples of how Blueberry described a system throughout the learning experience. In the posttest interview, he said:

> You plant the apple seed and then you have to take care of the seed. You have to water it. You have to give it sunlight and photosynthesis and then it will grow. And then you pick the apples and then you take it back to the factory to wash it and see if there's any defects. And you package it and then you send it to the packaging company. And then the packaging company will take it to the store. And then the consumer will buy it. They'll eat it. After it's consumed, I feel after it goes through the digestive system, then it just goes off into another system.

I asked Blueberry of other components involved in the process, he said "The labor, the money spent from gas, businesses and all of that is involved." This showed that he possibly recognized other components that contributed to the complexity. However, by not incorporating those components when describing a system to show a web of connections, his description was reductionistic.

Likewise, Blueberry's responses to the posttest Applesauce assignment were in a step-by-step manner. For example, in the growing apples section, he wrote:

> Inputs: Buying the seeds; driving to farm; digging a hole; planting the seeds; watering seed; man hours.
>
> Production and Distribution: Driving to the farm; picking the apples off tree; driving to factory; apples going through the factory; packaging and labeling; take it to delivery driver.
>
> Influences: The water; sunlight; the nutrients; soil.
>
> Outputs: Apple trees; supply jobs; helps the air with elements in air.

Blueberry explained simple connections rather than a web of connections that showed complex relationships. He also focused on two components rather than multiple components. In conclusion, he demonstrated systematic thinking, which is thinking in a step-by-step manner (Bartlett, 2001; Kasser, 2018), instead of systems thinking.

For Raspberry, she said that a food system was a complex system. However, she struggled to support her understanding of complexity. During the pretest interview, she said:

> [A food system] is complex of course, because there's a lot of different steps to breaking it down and understanding it more. Such as talking about the applesauce: how it starts—from beginning to the end—how details it has to go through all these stages and all that. Coz I didn't know how much it can be broken down… [Food systems mean] mainly breaking down the whole food item. Mainly that's what I'd think…like the growing, processing, consuming, and everything…. Economics of it, that's what I think. I don't know anything else to it.

Raspberry also had a difficulty completing the pretest Applesauce assignment. She responded with "I don't know" and question marks on several table cells. On the posttest assignment, she was able to identify some components without giving detailed explanations. For example, in the growing apples section, she wrote:

> <u>Inputs</u>: Apple seeds; soil/fermentation; sunlight/water.
>
> <u>Production and Distribution</u>: Dealing with transportation with trucks/[trans]porting goods from places.
>
> <u>Influences</u>: Not all beliefs, culture would grow apples.
>
> <u>Outputs</u>: Pollution/waste management; cars pollution/gas.

After the learning experience, Raspberry identified other components such as labor work, energy, and minerals and processes such as growing, packaging, and transportation when talking about a food system. Because she struggled to complete sentences, I asked her to use the Applesauce assignment to help her describe a food system. She said:

> For growing apples, you would first need the materials provided, such as the seed and water. And farmers would need the help as well as a tool, acres of how many land[s] you want for the soil and then sunlight providing. As for the production and [distribution] for growing apples. Like I said, dealing with transportation, because the transportation can still kind of give out to the stores and also import the goods from places to places. Then the influences, not everyone would believe in having culture of growing apples, and also depending on [the] environment, with their soil or either what they're raised as, born to. And then outputs of growing apples, I don't know if I answered that correctly, but I said pollution slash waste management can affect the outputs of how the results of the products that is produced, if it was either good or bad in a way.

Apart from the incomplete sentences, Raspberry explained each process of a food system separately. She did not discuss about various connections or a web of connections to demonstrate the complexity of a food system.

In addition to the interviewees, Jalapeño's responses on the Applesauce assignments demonstrated some level of systems thinking abilities. She made several connections between parts within a food system, made several connections between a food system and other systems (see subsection 4.5.1.2), recognized feedback loops (see subsection 4.5.2.3), and identified spatial and temporal dimensions (see section 4.5.3). More investigation would be necessary to confirm whether Jalapeño was a systems thinker, especially to demonstrate a web of connections and the understanding of complexity and wholeness. For the connections between parts within a food system, Jalapeño wrote at least two connections in most of the table cells. For example, in the growing apples section of the pretest assignment, she wrote:

> Inputs: People are going to have to plant it; they will have to water and take care of them; needing land space to grow them; people are going to have to pick them; need farm workers.
>
> Production and Distribution: Production—make sure enough space to grown enough; distribution—they will need to have the machines to carry them to storage.
>
> Influences: Watching for bugs; having enough water; weather.
>
> Outputs: Production—how much they grow.

For the posttest assignment, she wrote:

> Inputs: Farm land; machines; people; money; seeds; water; time to grow.
>
> Production and Distribution: Harvesting the apples; having enough to sell; trucks to transport.
>
> Influences: Temp.[temperature]; bugs eating away at plant; animals stealing seeds; knowing how to grow apples; having enough money to grow.
>
> Outputs: Harvesting the product; being able to have apples yourself; money gaining back from production.

4.5.1.2 Connections Between a Food System and Other Systems

This subsection focused on how students discussed about the connections of a food system with other systems, especially human health and well-being and the environment. More specifically, I analyzed data based on consequences of activities in a food system related to the goal of sustainable food systems in terms of limiting negative environmental impacts and improving socio-economic welfare (CIAT, n.d.). Students responded to the Applesauce assignments regarding connections of human health and well-being, and environmental impacts related to growing apples, processing applesauce, and consuming applesauce (see Appendix D). This section could also be considered as representing how students used the three pillars of sustainability: environmental, economic, and social (Purvis, Mao, & Robinson, 2019) in describing systems from more than one disciplinary perspective instead of viewing a system with a single discipline. The following paragraphs described how Nectarine, Apricot, and Jujube discussed about the connections between a food system and other systems.

Nectarine made several connections between a food system and other systems. For the pretest interview, he gave an example regarding how food was related to human health and well-being in terms of illness and socialization. He said:

> If the food that you eat makes you sick and you can't go talk to people because you were sick and stuck in bed. That would affect it. Obviously, that's not every day connecting, but it can affect each other. So, food systems can affect other systems, it doesn't necessarily have to. But it also is not completely isolated the whole time.

He also discussed that a food system is connected to an environmental system. As quoted in *Section 4.4*, Nectarine discussed about responsibly applying pesticides to minimize damage to the soil and plants, encouraging biodiversity to prevent disease outbreak instead of monoculture, developing appropriate practices for the environment, and responsibly utilizing and preserving resources. These examples demonstrated that Nectarine saw the two-way consequences of what a food system (e.g., pesticides) had on the environment (e.g., soil) and the environment (e.g., disease outbreak) had on the food system (e.g., monoculture). He said:

> The food system—food is grown in our environment. And the environment affects everything we do…. The way you grow the products: you try to not spray too many pesticides so that you're not killing all the soil and you're not spraying herbicides and killing all the plants everywhere. Monoculture, which is what

> we're doing in Indiana, isn't that great either. Because if you have something that affects corn, all the corns are gonna die…. But if you have a little bit of everything, the disease outbreak would be more isolated. So, thinking about things like that and just trying to develop practices that fit the environment and fit the climate. That will also help to not destroy what you're using. Like not just using up resources just because they're available, but actually try to use them in a responsible way. Preserve them.

Aligning with his verbal responses, Nectarine wrote on the pretest Applesauce assignment about several consequences both positive and negative. For example, he wrote that growing apples was related to human health and well-being because trees were a pleasurable sight and provided oxygen for breathing by converting carbon dioxide. He added that oxygen also had an impact on the environment. He added that processing applesauce related to having jobs for people. In order to grow apples, he wrote that a forest needed to be cleared to make room for planting, which reduced biodiversity. Similarly, "dig[ging] up the field" and deforestation were needed to build an infrastructure that processed applesauce. Lastly, he addressed negative environmental impacts, which were air pollution from the factory, transportation, machines (e.g., planter and tractor); runoff from pesticides; and soil pollution from packaging and disposable utensils in the landfills.

After the learning experience, Nectarine discussed about unintended consequences of a food system on the environment (e.g., soil contamination, pesticides killing pollinators) and farmers (e.g., a long supply chain reducing farm income and farmers having to keep producing more and having more land to produce) in the current farming situation. He said:

> I used to know how farms worked, but I think this [learning experience] has helped me to see a little bit bigger picture, like what affects the farmers. Not like I used to know that. So, farmers spray pesticides and then the pesticides can, you know, leak into the soil or whatever. Or if they spray it when the bees are out, you know, they're going to die. The bees may die or may take back to the hive and then the whole hive will die, which is what happened to one of our hives. Into more like, the farmers are doing all this and have so many fields because they have to produce so much because a lot of it is going to different things. So, like the first field trip we took to the student farm helped me see that farmers are producing a lot, but they're not really making a lot of money because they produce a lot. And then it goes through these different stages and by the time we sell the beef, it's not worth as much. So that's why I see farms everywhere in Indiana.

On the posttest Applesauce assignment, Nectarine wrote more connections between a food system and other systems. He wrote that working on a farm growing apples helped workers be in good health, labor got paid for their work, politics affected the price of the components, and therefore, the price of applesauce, and politics regulated ingredients in processing and packaging applesauce. In terms of the environment, Nectarine wrote that trees filtered air pollutants, roots prevented soil erosion, and planting different types of apples increased biodiversity. Other responses were similar to before but he added some more examples such as runoff came from parking lots, fume from garbage truck polluted the air, and applesauce packaging damaged soil health because of toxin in the plastic.

Next, I described how Apricot discussed about unintended consequences of a food system on the environment during pretest interview. She compared egg shell, which could decompose and did not have a high negative impact with indecomposable plastic, air pollution, and excess from food processing, which had negative impacts on the environment. Unfortunately, Apricot started to feel anxious during the interview and we changed our discussion from climate change to another topic. She said:

> After we eat the egg, we're gonna throw away the shell. And that's going to go somewhere. The shell's decomposable so it's not going to harm the environment as much as like wrapper from a processed food. Plastic doesn't decompose as well as an egg shell. That's not good for the environment. The fossil fuel and stuff when we run the machines—we have a lot of machines running. It's just putting a mix of chemicals into the air. It's not good for the environment. And trees will be much better… Excess that we have, stuff that we throw away during our time making that food, isn't good for the environment either, most likely. The factories that we have for the food production, I think it's hand in hand with climate change.

In the posttest interview, Apricot also made several others connections between a food system and the environment including driving less cars, not using Styrofoam cups, and shopping with reusable bags help reduce pollution. These were discussed in details in later sections because they also showed that she understood about the concept of feedback loops (see subsection 4.5.2.3) and how she intended to apply systems thinking (see section 4.7.1).

As Apricot later admitted that she was exhausted from filling out the table cells on the Applesauce assignments, she provided a few explanations nevertheless. On the pretest assignment, she wrote that trees produced oxygen for human health and well-being and air quality, trees helped ecosystem stability, tree growth improved soil health, processing applesauce was related to water quality, and feces from consuming applesauce was related to soil health. In the posttest assignment, she wrote that the growth of apples depended on the weather and an output from a food system included smog from burning fossil fuels when packaging applesauce. These examples showed that Apricot saw the two-way consequences of what a food system (e.g., growing and food processing) had on the environment (e.g., soil and air) and the environment (e.g., the weather) had on the food system (e.g., tree growth).

Next, I described how Jujube discussed about two-way consequences between a food system and the environment during the pretest interview. She explained that food processing polluted the air. In turn, food ingredients produced in an unhealthy environment had bad quality. She said:

> I think it has an effect both ways. Like the environment has an effect on foods and food also has an effect on the environment. Coz whenever we process food, some factories that process it use like a bunch of chemicals and stuff, which can cause air pollution, which affects the environment. And if the environment is not healthy, then that affects our foods because we won't get any healthy crops or animals could get sick and we won't have any good meat. So, it could like go either way in my opinion.

In the posttest interview, Jujube gave some examples of connections between food processing, resources, and air pollution as well as preservatives and human health. For negative impacts, she said:

> For example, chips, since they go through like a processing plant and all of that, that plant has to use energy somehow and a lot of oil. They have to create fuels somehow. So, a lot of that's air pollution and also, they put chemicals in the chips, which they can, to help preserve it. And that can be unhealthy to the human body if you consume too much of it.

For other impacts, Jujube discussed about how growing plants was good for the soil health and optimal use of chemicals did not harm the environment. She said:

> A healthy thing for the environment would be to grow stuff because it helps with the ground and it makes it tillage better. And not only does it help the earth, but it helps other species like humans and animals. The soil can get nutrients from the plants and help other plants grow. [Plants] do take things from nature to grow, but nature can easily refill that. Instead of going down and cutting a bunch of trees that will take years and years of regrow and we're not using. Most—some farmers don't use chemicals to help the plants, so it doesn't really kill the organic material around the plants and it's still good…. It depends coz some chemicals can be harmful to [the] environment. Some are just neutral. But the farmers who use chemicals to help their plants grow, it can be harmful in a way. It just depends [on] the amount of chemicals he use[s], I guess.

For the pretest Applesauce assignment, Jujube wrote that apples had a positive impact on the environment because apples naturally decomposed; growing apples took up land and water; growing apples helped the soil become richer, machines that processed applesauce caused air pollution, and consuming applesauce produced carbon dioxide. For the posttest Applesauce assignment, she added that apple trees supplied oxygen and applesauce could be processed without machinery to reduce air pollution, which was a suggestion rather than a statement like the first time she wrote about it. Jujube also made connections with the economic system especially in terms of demand and supply, which showed her understanding of feedback loops (see subsection 4.5.2.3).

The following paragraphs described that Kiwi, Blueberry, and Raspberry did not demonstrate systems thinking during the discussions about a food system and other systems. Kiwi explained about some connections between a food system and the environment during the pretest interview by describing his direct experience while herding cattle to another area every year. In the following quote, Kiwi shared that he witnessed a change in weather patterns as a result of the exhaust from factories and vehicles. As two-way consequences, what Kiwi described also addressed the impact of the change of the weather on the grass that his cattle fed on. He said:

> From what I see over in the Midwest, in the East differently than the West, is when we're running cattle out there versus here. Up here tends to be a lot cloudier and you can't really see the stars at night like you can out there. Coz the processing plants or the factories that are making food are sending up different stuff than it is out there… It's the chemicals that they're using or the stuff they're burning up through the pipes that are just causing fog and stuff. Along with the carbon dioxide from cars… It makes the climate here a lot different. Comparing out there to here is we get a lot less rain than we use to. And then out there they're getting more rain than we do now. When a couple years ago, it was the opposite. And they're actually having a lot of flooding these past few years on the land that we run cow through. So, the cows are actually eating more where they're not supposed to. And we just don't have a lot of ground that we use to let them graze on that we did a few years ago because the fog affected climate that's kinda just switch on us.

From this part of discussion alone, Kiwi could be considered a systems thinker for making connections between a food system and the environmental system. However, after triangulation, Kiwi could not articulate other connections with different parts of a system or other systems besides the ones he explained. He memorized the events from what he was taught or told rather than understanding those connections. Memorization also supported why Kiwi provided limited responses and explanations on the Applesauce assignments and the interviews. He had a difficulty making connections between parts within a food system and between the systems or gave an explanation that demonstrated an understanding about the complexity of a system. He should be explicitly taught how to come up with connections on his own and make connections between the events he already knew in order to become a systems thinker.

Similarly, during pretest interview, Blueberry discussed about a food system and the environment as a list of events from what he was taught or told without discussing how the events connected. Blueberry was asked to explain about consequences of a food system. He did not clearly explain the cause and effect of two-way consequences. He identified that emissions caused global warming, which limited rainfall and ended up killing the plants. He said:

> It will affect the plants, the carbon dioxide that's being released. Those gases will get stuck into the greenhouse—the greenhouse effect. And then global warming would happen. Yes, it would [affect the food system]. And then the earth would warm up. And then, we wouldn't get rain as much. It wouldn't water the plants like it should. And [the plants] die.

Later in the conversation, Blueberry said, "All the factories are polluting the air. So, it's just affecting the earth." He did not discuss further about the environmental aspect until the posttest interview. During the posttest interview, Blueberry concluded that a food system was good for the environment because growing plants would release nitrogen and oxygen which was good for the environment. Then, I asked Blueberry to talk more about pollution because he mentioned it during the pretest interview. He said, "Pollution would [be] like if we kept using plastic and stuff. But other than that, I don't see how the food system would have anything to do with that." I then asked him about food processing. He tried to make connections with a negative impact to the environment and then health from adding preservatives. He stated:

> The factories might not be so good for the environment, but I don't know. I don't know how they would—what they have to do during the factory to get it to a consumer. I mean maybe if they're adding preservatives to it. Coz preservatives aren't a real thing. It just makes it last longer. It might not be so good for the consumer.

Blueberry identified some events such as gas emission, air pollution from factories, greenhouse effect, and global warming regarding the environmental impacts. However, he did not connect these events together to describe about the negative environmental impact of a food system. Moreover, he focused on the growing aspect of a food system and excluded food processing until being asked. Overall, Blueberry focused on separate parts of a system and did not connect different systems, which is reductionistic and not systems thinking (Valerdi & Rouse, 2010; Verschuren, 2001).

Raspberry had trouble explaining her responses and did not seem to have sufficient knowledge to provide details. She often began sentences and did not finish them and was easily distracted. During the pretest interview, she often responded with “I don’t know how to answer it,” and “I don’t know how to explain it.” For the connections between a food system and the environment, she said:

> Depending on the environment, like, can affect the pollution like the quality of air. For an example, cars mainly can carry a pollution that can possibly kill kind of environmental situations. [Car] damages the crops or damages the food. I don’t know the whole like behind that situation.

Raspberry misunderstood the term environmental impact as how the environment affected a food system. Using salsa as an example, she said:

> For salsa, water or the healthy of the soil can affect the tomato in which water can also rot the tomato and damage it. And then, the soil depending on the type of soil that you use, can also affect in a way like damage or like the flavor of salsa.

After the learning experience, she still misunderstood the term environmental impact and proceeded to talk about the environmental factors that affected foods. She said:

> The pollution of the air would be of getting [on] like some veggies or fruit from another region. I would feel more sketchy about that. As for here, I feel like it's safer in some ways, but I know there is still problems with the air such as pollution and with cars and smoke can still affect the crops in ways like damage, the lack of them.

Raspberry only provided one-way consequence of an event between a food system and the environment. She might need to improve more vocabulary including the term environmental impact, how she organized her sentences, and how to make connections in order to develop this aspect of systems thinking ability.

In addition to the interviewees, Jalapeño made several connections between a food system and other systems on her Applesauce assignments. On the pretest assignment, she wrote on human health and well-being section that food safety in terms of biological and chemical contamination should be ensured. Regarding economic aspect, Jalapeño wrote about setting appropriate price and design, cost to process applesauce, and labor to package applesauce. In terms of environmental impacts, she wrote air quality; rich soil; air pollution from factories; using plastic for containers, and plastic waste after consumption. On the posttest assignment, Jalapeño wrote on human health and well-being section in terms of occupational safety while operating machinery (e.g., staying up to date with safety; using protective gear; and being trained to use the machines). Regarding economic aspect, Jalapeño wrote about having advertisement for the products; consumers having money to purchase; good packaging design; and sufficient inventory to restock. In terms of environmental impacts, she added about unused packaging and products that were not bought being discarded and became extra waste. Jalapeño's responses showed the connections she made in various parts of a food system and other systems that should be investigated more for her ability to discuss about complexity and wholeness of a system.

4.5.2 Understanding a System

As part of systems thinking ability, understanding nature, behaviors, or characteristics of a system is expected (Ben-Zvi Assaraf & Orion, 2010b; Meadows, 2008; Valerdi & Rouse, 2010). After open-coding and theming the data, three themes emerged regarding how students recognized and understood nature, behaviors, and characteristics of a food system. The three themes were a system's changeability, cyclic nature, and feedback loops. Each theme was described as followed.

4.5.2.1 A Changeable Food System

Systems are constantly changing unless it is in the state of equilibrium, where all inflows equal all outflows (Ateskan & Lane, 2018; Meadows, 2008; Moore, Dolansky, Singh, Palmieri, & Alemi, 2010). Within a system, there is a variable which can go up or down over time (Ponto & Linder, 2011). This subsection described the interviewees' discussions regarding a system's changeability.

During posttest interview, Nectarine talked about a change in the society since the farm processes were industrialized when more food could be produced and the amount of surplus exceeded. He identified a change in farming practices, farming purposes, and normalcy in society. Nectarine's discussion about changes also included the temporal dimension (see subsection 4.5.3.3) because he talked about a gradual change of a whole system that happened over time. He said:

> I think it was because when the plow was invented, farmers realized they could make more. And then after they realized they had more, it's like, 'we've got this extra, so what do we do with all this extra? Well, we can sell it to feed cattle.' And then, slowly the farms became more industrialized. And you had farmers who were feeding the cattle instead of farmers who are growing food for people. So over time, the farm industry was influenced by outside factors and it changed how farming was done…. It used to be you would just grow as much as you needed to support your family. And now most people are just getting jobs like librarians or you've got people who are lawyers and it's not so much growing what you need, but you're doing a job…. So, what is conventional, what is normal has changed. And so, the job of a farmer has had to change.

In addition, Nectarine discussed about another type of changes in a system. He addressed that an established practice would be difficult to change. On the posttest Applesauce assignment, he wrote, "Systems that have been in place are not easily changed if they work (for example, truckers instead of horses)." This showed that Nectarine understood the complexity to discuss about changes that involved variables (e.g., industrialization) that encouraged a change and an intention not to change (e.g., a practice that worked well).

Apricot discussed during pretest interview about relationships between technological advances that changed producers' and consumers' decisions to produce and consume. She recognized that contribution from research and what the media presented became a variable that change a system at a bigger level. This discussion also demonstrated her understand of feedback loops (see subsection 4.5.2.4). She said:

> We have a lot of technological improvements or discoveries that help us, or especially cancer research. It's really affecting the way of what we eat and what we choose to buy at the store. Coz a lot of people are researching cancer right now. And so, they're telling you what's not good to put in your body. And even right now, for diets like the keto diet. All the research that we do, research everywhere, you know, affecting the way of what we choose to buy because that's what they're telling us that we need to put into our body. You know, that's what we hear from sources like the radio, or what we read, what we're trying to research what to diet. And that's gonna tell us of what we think we need to buy, what we think is good for us. So, everything we see around us or the research

> people are doing affects what we buy. And then, that in turns affect what people produce because that's what we want.

Apricot also talked about a change in the nutrient level from planting at the same field repeatedly. Apricot's discussion about the change also included the temporal dimension (see subsection 4.5.3.3) because she talked about a gradual change of the nutrient level that happened over time. She addressed the relationship between two variables (e.g., plant growth and nutrient level) within a system (e.g, the environment). She said:

> If we're planting something over and over and over again into the same soil, that's going to just take away all the nutrients from that soil. So, we have a piece of land 20 years ago and it was really nice. And we planted a vegetable. And that vegetable grows. And then, next year we replant the vegetable, we replant the vegetable. Eventually that vegetable is not going to grow. It's gonna have issues. Just coz the soil lost its nutrients. And so, the same action can have a different effect over time as we wear on with the environment.

During Jujube's pretest interview, she discussed about a change in the food systems regarding a major consumer from dinosaurs historically to humans at the present time. This showed that she recognized a considerable change of a variable in a system. She did not elaborate how this change affected the whole system, but she later added in the conversation, which could be implied, that she thought human consumed a much wider variety of plants and animals compared to dinosaurs. She said:

> The food chain has changed over the multiple years. And right now, I'll say that humans are the biggest consumer for everything. And probably back before humans were even here, animals, like maybe dinosaurs or something like that, would be the biggest consumer during that time. And over time it has like gradually changed. In the future, I think we'll probably still be the biggest consumer. Maybe if humanity were to be wiped out, then maybe animals will become the biggest consumer again. But, as far as I know, I think that we're gonna be the biggest consumer throughout the rest of our lives.

Kiwi discussed during the pretest interview about the same topic as Apricot about a change in the nutrient level from planting at the same field repeatedly. Unlike Apricot, Kiwi merely described the event of nutrient loss to the point of no return after growing the same crops repeatedly rather than addressing about how that could relate to a system. He said:

> If you take the same crops and grow [them] over and over again this year and the past, your nutrients in the soil will dissipate to the amount when they don't show up anymore. Even if you add the plant that add the rich nutrients to it, it wouldn't be able to send off enough nutrients to add it be as rich as it used to be. And you kindof screw the pooch on that.

Later, Kiwi discussed about an event of a negative impact of how changing a regular practice could lead to lower yield and diseases. This only focused on the production aspect of a food system. He said:

> If people purposely changed something that they were doing the same year, the ground can get a lot less neutralized and it could actually grow worse crops than the previous year. And then it could make bacteria or something that weren't in [the ground] last year, more susceptible, or grow a lot more quantities, like the romaine lettuce for example. And then you gotta take it all out and try to regrow.

Kiwi also talked about an event of a negative impact of a change in land use when more people moved in and contaminated the soil which affected the farming field nearby. He said:

> If you start out in a big open country and then people start taking over different fields and [people] just dump their sewer and water and trash all over the place, the farmers [a]cross the road aren't gonna have as rich soil coz it's been contaminated per se. And it's just not as rich or as good as it used to be. It tends to affect how your plants used to grow versus how it didn't grow with the community closer to it or the city closer, I guess.

Kiwi demonstrated that he recognized changes especially when they were closely related to his livelihood. His tone indicated that he was not in favor of changes. He did not elaborate his discussions about how the system was affected by these changes. Recognizing these events would be a good foundation to teach Kiwi in describing a system and making connections within a system and between systems (see section 4.5.1).

Blueberry also briefly mentioned about a change during pretest interview focusing on his interest in health and nutrition. He said, "Small things can cause big effects. Just like eating right, you can lose weight. Something small but can have a big impact." He did not discuss a change that affected a system as a whole, however.

4.5.2.2 Cyclic Nature of Food Systems

According to Merriam-Webster dictionary, cycle refers to "a course or series of events or operations that recur regularly and usually lead back to the starting point." When the interviewees described about a food system, they also talked about where a food system ended or what happened to the food system after consumption. In the beginning of the learning experience, the interviewees did not perceive the nature of a food system as being cyclic. They addressed a start and an end point of a food system. Specifically, interviewees stated that a food system of applesauce started as a seed and either ended when we ate or ended in the toilet. For Apricot, she said a food system ended after the food was digested. She stated:

> Food system to me is how it starts and where it goes from where it starts. So, the applesauce—it's obviously gonna start as [a] seed and it's going to be in probably like a tree farm of some sort. So, there's gonna be workers that have to deal with that. And then it's gonna go somewhere. It's going to have to be processed. And then it's gonna be taken to the store. And then what happens when it's at our house. It gets eaten and it goes through our body—that's another process that you have to think about when you're shopping. What happens when it goes through your body. And then you know, obviously ends up in the toilet.

Kiwi and Blueberry said a food system ended when the food was eaten and what happened afterwards was considered part of another system instead of a food system. Raspberry said a food system included a beginning to an end without further clarification. The following paragraphs described how Apricot, Jujube, Kiwi, and Raspberry discussed the cyclic nature of a food system after the learning experience.

During the posttest interview, Apricot stated that a food system was a cycle. She added, "[The cycle] could end, if we run out of resources and food and stuff. But it's not ending right now, I don't think." In addition to the interview, Apricot wrote feces as a response to the *input* for growing apples in addition to the *output* of consuming applesauce, which showed that the output returned to a food system to become an input in the cycle of the system. Jujube discussed that a food system did not end but continued in a cycle. She said:

> In the beginning, I didn't really see the food system as [a] system. I saw it more as a chain. Like this happens, that happens, that happens, then it's all done. But after the lesson, I learned that it's like a continuous circle. And after the food's done, it's thrown away. It's decomposed—used for growing and all of that. And it can either go to growing food for animals and a lot more.

She provided an example to support decomposed food becoming nutrients for growing more food in a step-by-step manner. She said:

> It's like the life cycle of food. And basically, if you were to take an orange and you were to grow an orange tree, take the orange, you would have it transport by truck, then [it] would be taken to the store. And then somebody would buy it from the store. And then they would eat it. And then maybe with the remaining oranges, they might use it as compost for their garden and then it starts all over again. And they could probably use that orange compost to grow more orange trees…. There's really no end, I think it's just like a big loop.

Jujube also said that feces and water could eventually return to the food system. She said:

> Poop goes through the sewage system. And then through the sewage system it gets cleaned out through the water. And then the water that was used to carry it is cleaned thoroughly and then put back in the city where people can drink it. It goes into another process or system. And then it may end back up in the same system that [it] was in the beginning.

Kiwi said a food system "get[s] recycled and the cycle starts over again." He acknowledged that after food was eaten, it went to the bathroom, back into the ground, and added nutrients into the soil. Raspberry said, a food system "doesn't really end because you can reuse the waste or disposal or recycling it."

In contrast, Blueberry was the only interviewee who did not perceive the nature of a food system as being cyclic. Instead, his perception of isolated parts could be one of the reasons he defined a clear boundary for a food system and therefore, unable to see a cyclic nature of a food system. He said, "After [food]'s consumed I feel after it goes through the digestive system and they just goes off into another system."

4.5.2.3 Feedback Loops in Food Systems

In a system, there is a process of feedback in which the output of a system is fed back around to regulate the system (Ponto & Linder, 2011). There were several evidences that Nectarine, Apricot, and Jujube recognized that a food system operated through feedback loops. Because a food system is complex and there are different processes and components involved, feedback loops occur in various different parts of a system. The examples showed that the three interviewees understood that an activity or an action could be a factor that regulated (e.g., increased or decreased) other activities in a system.

During the posttest interview Nectarine demonstrated his understanding of a system's feedback loops while defining a sustainable food system. He addressed the balance between appropriately use of natural resources while ensuring that food was produced sufficiently. He explained that excessive production and purchase order encouraged food waste and overuse of natural resources. He stated:

> [A sustainable food system is] a system that feeds everybody and those who needs food, and does it while making the best use of the Earth's resources, like farming smartly…. Planning for the future and trying to make sure that you're not just depleting the soil and killing off plants left and right. So that your plant can grow but that you're trying to still feed everybody…. You're not wasting oil to make fuel for machines to get to plow fields and fertilize fields. If you need a thousand acres of fields, farm a thousand acres of fields, but not farming 10,000 acres of fields. Because if you don't need that much food, don't make that much food. I'd say one way of doing that is like the restaurants throwing out food. If they're going to throw that much out, they're going to have that much more come in. So, don't throw that much out and don't have that much more come in. And then you'll need less food grown, which will be less fertilizer, less oil use.

Nectarine also discussed about supporting a sustainable food system. He said he would support local farmers and not support businesses that contributed to food waste in order to send the message to them. By lowering the demand, Nectarine believed that it would help the food businesses generated the desirable change. He said:

> Probably buying local food—direct from farmer to help support the farmer for one thing. And because that will go through the feedback loop to large farmers or maybe a bit large businesses. And I can say like, 'I'm not supporting you because you're wasting food, because I don't believe in what you're doing.' Not like, you're terrible. But I think it needs to change.

In addition, Nectarine wrote on the posttest Applesauce assignment, "More or less apples will dictate the price of apples." This demonstrated another example of mechanism of a variable (e.g., quantity of apples) that could increase (i.e., positive feedback loops) or decrease (i.e., negative feedback loops) another variable (e.g., price) in the system.

The next examples were from Apricot. During the pretest interview, she talked about the positive feedback loops in a similar way that Jujube did about the power of consumer. Apricot recognized the influence that a variable (e.g., information) had on other variables (e.g., food purchase decisions, production decisions). She also talked about consumer's demand determining what was being produced. She stated:

> Everything we see around us or the research people are doing affects what we buy. And then, that in turns affect what people produce. Because that's what we want… I think everyone is part of a food system. Coz we're all, like I said, what we want is produced.

After the learning experience, Apricot added specifically about raising awareness to the consumers to approve (i.e., positive feedback loops) or disapprove (i.e., negative feedback loops) a product to alleviate environmental problems. She said:

> If I told people about what we are doing to our environment and if you stop buying a certain product that maybe the making of it is bad for the environment, then they'll stop producing it. If a lot of people stop buying it, they won't have a need to produce it anymore. If I told people about what we're doing to the environment—educating them, like you are, then people would be more aware, like you've made our class more aware. And we will be able to do something and change it.

Apricot also recalled one of the lessons that taught about feedback loops with multiple variables (e.g., resources, gas price, car use, pollution). She shared:

> I never knew why gas prices were going up and down. And now I get it as more of a system. They're not just doing it because they want us to spend more money, but we're running out of resources. So, gas is going to slowly start getting more and more pricey because we are using it. And we were also like, gas prices go up, we use less gas because gas prices go up and we don't have money for that. And then we put less pollution, you know. When we drive less, we pollute less, but that's only because of the gas price is more because we use it. So that's kind of the system.

Lastly, Jujube discussed several examples about feedback loops in food production. First, Jujube wrote on the pretest Applesauce assignment that (1) consumers buying apples which contributed the money back to farmers to buy more seeds to plant more apple trees; and (2) consumers' satisfaction of applesauce making consumers continue to buy the products. During the pretest interview, she addressed the positive feedback loops that enhanced the direction of change (e.g., production increased when sales increased) and the negative feedback loops that reverse the direction of change (e.g., the business closed because people stopped purchasing). She said:

> If people were to consume applesauce and they liked it, they would want to buy more of applesauce of that brand or maybe different brands. And so, after consuming applesauce it can either convince them to buy more or it could decrease their liking of applesauce. If a lot of people like applesauce, then there's obviously gonna be more companies making applesauce. But if people stop buying applesauce because they don't like it, then the applesauce business will go bankrupt. And then the applesauce business will close.

In addition, Jujube talked about the amount of consumption (e.g., consume a lot) regulating the pace of the production (e.g., quicker) and how much to produce (e.g., produce a lot). She said:

> If we consume too much food, the process of food will have to go quicker. And they will have to produce more depending on how much we consume at once. So, if I consume a lot of meat in one day, they will have to produce a lot of meat later on in the future for it to be like an equal ratio.

After participating in the learning experience, Jujube discussed about the negative feedback loop that led to a more desirable system by using the power of consumer demand to stop supporting products that had a negative impact on health (e.g., preservatives) and the environment (e.g., packaging). Conversely, she stated that supporting fresh food was a positive feedback loop to bring more fresh food to the stores. She said:

> If I choose to buy packaged items, the store would see that more people are buying packaged items than fresh foods. And so, they'll end up making more packaged items, which would have to go through like a plant and everything. And a lot of chemicals are used to make the packaging and all of that and also to preserve the foods. And then if I were to pick fresh foods and the store were to see that more people were buying fresh foods, more fresh foods would end up going into the store than packaged foods.

In contrary, Blueberry did not use the concepts of feedback loops to discuss the importance of consumer demand. Blueberry recognized the influence of consumer's voice, but unlike the examples above, he did not think that buying power regulated the company's decision. Instead, he considered a linear behavior instead of a feedback loop. In the posttest interview, he said:

> We're the ones buying it. So, we can't really do anything if it already comes in a plastic container. So, we need to reach out to the packaging company to see if they can change the packaging instead of using plastic. [If they said no], then they keep polluting the Earth.

In addition to the interviewees, Jalapeño's responses on the Applesauce assignments demonstrated that she recognized feedback loops. On the pretest assignment, she wrote that "being satisfied with the taste [of applesauce], people buy more." More investigation would be necessary to allow Jalapeño the opportunity to discuss more about feedback loops.

4.5.3 Viewing a System

A system thinker is expected to view a system from multiple perspectives, in temporal dimension, and in spatial dimension (Lee et al., 2017). The analysis was based on how students used different perspectives to view a system and how they considered time and place related to their understanding of a system (Ben-Zvi Assaraf & Orion, 2010b; Meilinda et al., 2018; Ponto & Linder, 2011; Valerdi & Rouse, 2010).

4.5.3.1 Perspectives

In order to better understand the complexity, using multiple perspectives to look at a situation is encouraged (Ponto & Linder, 2011). In *Subsection 4.5.1.2*, I described how students viewed systems from various disciplinary perspectives. In this subsection, I described how students who demonstrated systems thinking discussed about other people's perspectives that they used in viewing a system or a situation. Some students also used a systems view or started to take a systems view as a new perspective in viewing a system or a situation.

During the pretest interview, Nectarine demonstrated that he was aware of other people's perspectives, which could be different from his. As he talked about the Applesauce assignment, he thought that the provided topics: *human health and well-being* and *outputs,* were almost no difference because ultimately, he viewed everything as being connected. In another word, he used a systems view to discuss about food systems. He said:

> I would have a hard time determining exactly what human health and well-being is. I think I thought of human health and well-being as the consequences of good or bad of what was happening. And that's really the outputs which human health and well-being is over all, in general, benefits the humans. So, I think there's a fine distinction between the two. I think someone else might find the distinction a little bit easier to grasp. But I didn't personally grasp it as well. I think they were similar as I looked at it. But someone else with other viewpoints can obviously see it as something else differently.

For the posttest interview, Nectarine discussed about how he considered his siblings' perspectives to find resolution when a conflict occurred. Nectarine considered series of events that might lead up to the conflict rather than an immediate event. He said:

> Say, I get [into] an argument with my siblings or two of my siblings have an argument. I can look beyond, he did this, she did that too. Like who-- what really caused the argument more. And I can be understanding because I can say, 'well, you got me mad, but you were upset because you've been gone all day. And you've been working, or you've been at this obligation.' And like, my family doesn't like to go places, so we're all home bodies. And so, I can say, 'well, you were gone all day and you've had all these things that have affected you and you're getting upset at me, but it's not really my fault.' So, I can, or if there's other problems, I can see or try to find us a solution to a problem that's not just conflict.

During the pretest interview, using a systems view, Apricot recognized that looking at a food system as a whole with smaller details was seeing a system from another perspective. She thought that it was more difficult because it was untraditional and there were many aspects involved. She said:

> I think it's just the fact that a lot of us in this class, we haven't really had to think about-- know where stuff starts and where things end. We haven't had to think about that at all. And I think it was just putting everything into a new perspective especially like the applesauce. And there were so many things to think about…. People wouldn't think about the work that had to be put into growing the tree and then getting the apple and then processing it. So, that was hard with this, thinking about all of it. And that's because there're so many different aspects in the whole thing.

Apricot also discussed that consumers had been influenced by perspectives from the media and latest discoveries. She elaborated how these perspectives from others affected the consumers and growers' decisions, which affected the system entirely. She said:

> That's what we hear from sources like the radio, or what we read, what we're trying to research what to diet and that's gonna tell us of what we think we need to buy, what we think is good for us. So, everything we see around us or the research people are doing that affects what we buy. And then, that in turns affect what people produce because that's what we want.

During the posttest interview, Apricot told me a direct experience at her work place that a customer's perspective to reduce food containers and use biodegradable materials influenced her to look at a waste management problem more closely. She said:

> A girl came into our restaurant the other day and she was really mad because we only had Styrofoam cups, because they're not biodegradable and that's also bad for the environment. Even though it's just a cup, like it wasn't grown anywhere. It's just Styrofoam. And then she was like, you can keep your straw and your lid. And since then I've thought about doing something about that: like getting rid of the Styrofoam cups even though it's out of my control. So maybe I'll take reusable bags to the grocery store and just recycle more.

During the pretest interview, Jujube talked about a simplistic perspective regarding applesauce. She addressed that it was not an inclusive way to view a system, which showed that she potentially recognized a more complex perspective or even a systems view. She said:

> Even though most of us know where applesauce comes from, we just automatically think that apples just go through—they mush some up, and then they are put in containers. When it could be much more different than what we think. There's a lot more into applesauce than what we think there is.

During the posttest interview, Jujube discussed about the cyclic nature of a system that she did not think about prior to the learning experience. After Jujube told me that materials in the sewage system might end back up in the food system. I asked if that idea was repulsive to her. She compared the idea with the experience during the field trip where she ate the carrot that also contained animal waste. She said:

> I mean, well, I did eat a carrot with manure on it. I mean eventually it has to go somewhere as po--. There's always manure and poop in the soil. It's basically all in the soil. And there's really nothing else besides maybe dead leaves and like rocks, sand, clay. But a lot of it is just decomposed material of different things.

The following paragraphs described about how students did not ideally consider other perspectives as expected from a systems thinker. Kiwi and Blueberry showed some evidence that they did not contemplate other perspectives. While Raspberry recognized other perspectives, but did not demonstrate the implication of how she viewed a system. Rather, she specified a single event or a part of a system.

During the pretest interview, Kiwi explained to me why he considered his diet to be unhealthful. He acknowledged other people's opinions but he did not really listen. In addition, what he discussed did not demonstrate that other perspectives affected a system or how he viewed the system. He said:

> Coz the only greens or vegetables that I've grown and eat are potatoes, peas, or green beans. I don't eat anything, ah corn, but I don't eat anything else. I'm fine. I never get sick. Everyone's like, if you don't have carrots or less you're gonna get sick. But I haven't been sick in years. So, I ain't gonna about to start it.

For the posttest interview, Kiwi did not instinctively recognize the new perspective that the sustainable food systems learning experience tried to teach. He said, "It was mainly stuff I've known before," which he referred to the content knowledge from growing up on a farm and having an uncle who worked at a food processing plant. However, when we talked about food as a system, Kiwi admitted that he did not think about post-consumption and the cyclic nature of a food system prior to the learning experience. Therefore, unknowingly, he gained a new perspective.

During the pretest interview, Blueberry elaborated on why he strongly disagreed with the questionnaire item, *I value other people's opinions of the situation*. He said, "I do to some point. But if they're just gonna like argue with me on something that I don't care about, then I'm not gonna care about it. You know what I mean?" This also reflected in what Blueberry explained to me about his career aspiration. He said learning about a food system could be beneficial to him if he wanted to further his study in agriculture, which he did not. He said:

> If I wanted to go into agriculture, then it opens my spectrum of what I could do after school. It's just not [what] I have in mind because I want to follow my weight training and all that. [Learning about a food system helps with] knowing how much fat is in something or protein, or carb. [For consumers], just knowing what's grown, and produced. It really like change[s] your mind what brand to buy from. Maybe this brand will be healthier than this brand, or vice versa.

On both of his Applesauce assignments, Blueberry's responses were also about food safety (e.g., infection, cleanliness) and nutrition (e.g., vitamin), which reiterated that he did not consider other perspectives that he thought were irrelevant to weight training.

For the posttest interview, Blueberry told me that he was preparing to move out of Indiana to a Southern state. Therefore, he did not find Indiana examples in the learning experience to be useful to him personally and suggested that the examples should not be limited to Indiana. He said:

> I will be out of Indiana. Maybe like give [the learning experience] a boarder range. If I'm not gonna live in Indiana and it's like what Indiana do and where would I go. I'm moving down south. They will grow different foods. And their

> soil might be different and you might do things a little differently, like with packaging and all that.

As part of a U.S. food system, there were similarities that could help Blueberry understand the food systems of the two areas. Refusing other perspectives was not useful for understanding the complexity.

Raspberry talked about perspectives in terms of culture and tradition. In the pretest interview, she gave an example about culture and religion that might not consume applesauce without discussing about food as a system. She said:

> Tradition maybe, or culture like maybe some people of religions does not eat applesauce or like apples or something like that but Americans do or something. Like from another example, we have a Muslim brother and he doesn't eat pork. So, it's kind of like that but like in this example of applesauce, though.

Later during the posttest, she talked about the influence of culture and regions on growing. She said, "Not everyone would believe in having culture of growing apples and also depending on environment with their soil." However, she did not elaborate on how the perspective influenced her in viewing the food system as a whole.

4.5.3.2 Spatial Dimension

A systems thinker is expected to consider spatial dimension when discussing about a system and relationships within a system (Lee et al., 2017). Spatial dimension referred to concepts regarding a continuous area (i.e., space) and a particular position (i.e., place). In this subsection, I described how students used the concept regarding space when talking about a food system and how the factor of place was related to student's understanding of a system.

The examples that showed how a systems thinker viewed a system in spatial dimension were from Nectarine and Apricot. On the pretest Applesauce assignment, Nectarine identified having a space in growing food as well as having a space for infrastructure to process food. Moreover, he addressed that the space for a food system came from replacing the forest and the field, which also reduced biodiversity. He wrote, "[Growing apples] may clear a forest/reduce the biodiversity to have room to plant the [apple] trees," and "[for processing applesauce], the building may clear forest or dig up a field to have space." After the learning experience, Nectarine discussed that Indiana farmers required a large space to produce food to make enough money because of various stages and factors in a food system. This showed his understanding of relationships between space, growing process, land use, economic activity, and biodiversity. As quoted in *Subsection 4.5.1.2*, he said:

> The farmers are doing all this and have so many fields because they have to produce so much because a lot of it is going to different things. So, like the first field trip we took to the student farm helped me see that farmers are producing a lot, but they're not really making a lot of money because they produce a lot. And then it goes through these different stages and by the time we sell the beef, it's not worth as much. So that's why I see farms everywhere in Indiana.

Apricot recognized that there were different food systems based on geographical and cultural factors. She discussed during the pretest interview that she recognized the influence of food grown in a different place and the culture and knowledge about the food to distinguish different food systems. She said:

> What we want we go to the store and buy. And it depends on where we're from, too. What store do we go to buy different foods. I go to Walmart. But my stepmom, she goes to some Asian store that I can't pronounce I'll be honest. And she buys a bunch of rice. And that's where she is in the food system. She gets food. Where she buys, it comes from different places, not here in America. Stuff that we can't even grow here. I buy stuff that's grown here, just coz that's what I was raised into. That's what I eat. So obviously I don't know about vegetables and fruits from [a country in Asia] coz I wasn't raised there. So, I wouldn't know how to eat that. So that's why I'm part of the food system. I just eat stuff that I know.

Other examples showed that students recognized spatial dimension related to an event or a situation but they were not elaborative enough to demonstrate how the students used the spatial dimension to view a system. Kiwi had a discussion during the posttest interview regarding the natural state of the land. He explained about the human intervention that contaminated the soil. In nature, the life cycles of plants and animals enriched the soil. He said:

> So, you have a plant. The insect eats a plant and it's turned into compost or eject composts that'll help the soil. And then where it dies or craps, that helps the soil where those grasses going and then they kinds of environ--. I'm not sure where I was going with that, but it helps like the environment, it stays natural. You don't have any chemicals or humans messing it up. So, it continues to stay how it used to be. And sometimes that's the best food plants or land you can find. But it's hard to find these days since we've pretty much touched it everywhere. We actually have the state parks and everything where we're not allowed to decompose

> [dispose] trash or mess with any animals and plants or leaving manmade things inside the park. So that's probably one of the few places that the environment and their food chain and their plant chain has not changed and has stayed the same for years or since Reagan enacted the laws.

In responses to what could be done to solve the problem that he raised, Kiwi said:

> Clean up a lot. Like respect the land that we have [been] given because it wasn't ours to take. We just took it and then we turned around and destroyed it. So, if we cleaned up the mess that we made, we're more respectful to it are the way our food is made would go back to how it was when we first came over.

When asked to talk more about the strategies, Kiwi could not elaborate the suggestions. He seemed to be repeating what he was told rather than synthesize or apply the ideas. He said, "Don't throw your trash out of the truck or your vehicle. And don't leave your trash on the ground or anything like that."

Blueberry discussed about the spatial dimension which was presented in *Section 4.5.3.1* regarding the different perspectives when he told me that he was preparing to move down South and did not appreciate Indiana examples presented in the lessons. This could be interpreted that he viewed the two areas to be completely different, rather than having some connections. He did not recognize that he could not apply the knowledge about Indiana after he moved out of the state.

While Raspberry walked me through the applesauce processes during the posttest interview, she mentioned farmers' need for acres of land for the soil once. However, she did not elaborate. Similarly, Jalapeño's responses on her Applesauce assignments showed evidence that she thought of spatial dimension. On the pretest assignment, she identified the space needed to grow food. She wrote, "Growing apples—needing land space to grow them" and "make sure [there is] enough space to grow enough [apples]." On the posttest assignment, she also identified the space needed to display the food product in the store. She wrote, "Stores have the space to shelf [applesauce]." More investigation would be necessary to allow Jalapeño the opportunity to discuss more about the spatial dimension.

4.5.3.3 Temporal Dimension

A systems thinker is expected to consider temporal dimension when discussing about a system and relationships within a system (Lee et al., 2017). In this subsection, the focus is on how students considered a dimension of time in their thinking such as a time horizon or a length of time under consideration (Ponto & Linder, 2011) and how students considered what had happened in the past and what would happen in the future. Factor regarding time is important in promoting sustainable food systems, especially thinking about time in short-term and long-term periods.

The two examples of how a systems thinker used temporal dimension to view a system came from Nectarine. During the posttest interview, he discussed about how the past event influenced the farming situation at present and into the future. He said:

> The Dust Bowl of 1930s…so that was over-farming cost the ground cover to go away. And then when all the ground dried up, there was so dusty. And then, the winds picked up and it was the past events and it was farming in the past but it greatly affected their present because they were experiencing dust and dust storm everywhere all the time. And the past affects the future because it’s kind of all just one—time’s like a river.

The second example was from Nectarine discussing about retrospection during the posttest interview. He discussed about agriculture and the change of lifestyle from the past. As quoted earlier in *Subsection 4.5.2.1*, he said:

> I think it was because when the plow was invented, farmers realized they could make more. And then after they realized they had more, it's like, ‘we've got this extra, so what do we do with all this extra? Well, we can sell it to feed cattle.’ And then, slowly the farms became more industrialized. And you had farmers who were feeding the cattle instead of farmers who are growing food for people. So over time, the farm industry was influenced by outside factors and it changed how farming was done…. It used to be you would just grow as much as you needed to support your family. And now most people are just getting jobs like librarians or you've got people who are lawyers and it's not so much growing what you need, but you're doing a job…. So, what is conventional, what is normal has changed. And so, the job of a farmer has had to change.

In addition, Nectarine recognized the factor of the length of time to conduct an activity, but not for the whole system. When he responded to the pretest Applesauce assignment, he wrote, “Time spent pruning the tree” and “wasted time eating [applesauce].” He also talked about how the same action can have different effects over time depending on the state of the system by discussing about the electromagnetic pulse. He said:

> An EMP-electromagnetic pulse would, if it happened nowadays, it would completely damage all of our systems. Because it would destroy electronics and electronics are everywhere. Your phone, there’s a telephone over there, whatever that thing is, and a TV. And probably a computer because I’m noticing keyboard. So those will all be destroyed, in addition to modern cars and everything else. But if it had happened when there were no electronics, nothing really would’ve changed.

Other examples showed that students recognized temporal dimension related to an event or a situation but they were not elaborative enough to demonstrate how the students used the temporal dimension to view the whole system. Jujube talked about what she thought of the future for the health of the environment during the pretest interview. She said, “I think that our environment will become poorer. And we have to figure out other ways to grow crops because of air pollution and water pollution.” Similarly, Apricot also mentioned in the pretest interview indicating that the environment was going “downhill” and needed to be improved.

As discussed earlier in *Subsection 4.5.2.1* regarding how students recognized the changeability of a system, Apricot talked about the repeated actions that changed the state of a soil condition during the pretest interview. She said:

> If we’re planting something over and over and over again into the same soil, that’s going to just take away all the nutrients from that soil. So, we have a piece of land 20 years ago and it was really nice. And we planted a vegetable. And that vegetable grows and then, next year we replant the vegetable, we replant the vegetable. Eventually that vegetable is not going to grow. It’s gonna have issues. Just coz the soil lost its nutrients. And so, the same action can have a different effect over time as we wear on with the environment.

Similarly, Kiwi also discussed about adding lime to the soil for growing corn during the posttest interview. He said:

> So, you got rich soil and that's good. First year, that's fine. Second year, you get a little less rich soil. So, you add lime to it. Now that soil is going to react to that lime. And it's gonna need that lime over years. So eventually that crop—it used to be nice sweet corn, but now you happen to depend on that lime and the chemicals that keep sweeten it. Overall, it just probably starts to taste differently than what you’re used to. And I guess chemicals—they're manmade so they're going to have problems. They're gonna mess up and they're going to hurt something eventually too. Or else if you keep it natural like it has been for decades and decades, it's not going to change as much as chemicals would do to it.

In addition, Kiwi discussed about a factory in the past that did some damage to the environment conditions around. He shared:

> There's an old dog food plant out in [a town] that was shut down. And the land around it still has not grown grass back. Like they tore up asphalt and they put down seed and everything coz they tore everything but the big factory down. And they still cannot grow because of what they were sending up through the air. The environment around it is still dead. They closed down probably when I was around eight or nine. And stuff has still not grown back. At this point after years, I don't think it's going to be the way it was. I'm sure grass would grow back—some kind of grass, but I don't think a farmer's going to go, 'hey, I'm going to pick this up' because it's not going to produce anything.

During the posttest interview, Raspberry contributed to the conversation about temporal dimension by discussing the car and pollution in the past and in the future. She said:

> For the past there was less cars obviously. In which like there was less pollution there. But as of now, the more people that are driving the more cars cause pollution and can [have an] effect on more of the future.

Apart from the interviewees, Jalapeño's responses on her Applesauce assignment showed evidence that she factored in the temporal dimension. On the posttest assignment, she wrote, "Time to grow [apples]" and "time [to process applesauce]." More investigation would be necessary to allow Jalapeño the opportunity to discuss more about the temporal dimension.

4.6 Instructional Design for Systems Thinking

This section addressed the second research question to explore how the instructional design of the sustainable food systems learning experience helped students learn about, engage in, and practice systems thinking. I described students' perceptions and experiences toward the overall learning experience and the three main instructional components: (1) Applesauce assignments; (2) online lessons with worksheets; and (3) experiential learning activities, as well as their roles in this study. For each component, I described how the instructional design features helped or hindered their learning about systems thinking in the context of sustainable food systems. An overview of the engaging and hindering factors of the three instructional components described in the following sections was presented in Table 4.3.

Table 4.3: Summary of Engaging and Hindering Factors of the Instructional Design that Helped and Hindered Systems Thinking

<table>
<tr><th rowspan="2">Instructional Components</th><th colspan="2">Students' Perceptions and Experiences</th></tr>
<tr><th>Engaging Factors</th><th>Hindering Factors</th></tr>
<tr><td>Applesauce assignments</td><td>• Initiate thinking
• Help students make connections
• Encourage a new perspective</td><td>• Confusing
• Too much writing
• Exhausting</td></tr>
<tr><td>Online lessons with worksheets</td><td>• Challenge students to think
• Unique and effective
• Informative and interesting
• Self-explanatory</td><td>• Difficult to come up with answers
• Too many videos
• Insufficient time
• Insufficient guidance/examples</td></tr>
<tr><td>Experiential learning activities</td><td>• Enjoyable
• First-hand experience of concepts taught in the lessons
• Applicable to farming and gardening projects</td><td>(Did not appear in data)</td></tr>
</table>

4.6.1 Overall Perceptions Toward the Learning Experience

Based on the posttest questionnaire evaluating students' perceptions of the usefulness and effectiveness of the learning experience, students in this study had a positive experience overall (see Table 4.4). All students reported that they could use what they learned in this experience, they had a greater understanding of how their food choices are related to the food systems as a whole, and they would recommend this learning experience to other students. All students agreed that interacting with guest speakers and visiting the diversified organic farm were valuable to them. A majority of students reported that the learning experience challenged them to think, they liked learning from examples in Indiana, and volunteering at the food pantry was valuable to them. Three quarters of students reported that they developed the ability to think in systems thinking way, the online lessons provided an effective learning experience, and the worksheets effectively helped them learn the online lessons. Finally, 67% of students reported that the learning experience provided skills and techniques directly applicable to their future careers.

Table 4.4: Students' Perceptions Toward the Learning Experience (N = 12)

Items	Percentage of Agreement
I can use what I learn in this learning experience.	100
I have a greater understanding of how my food choices are related to the food systems as a whole.	100
I'd recommend this learning experience.	100
Interacting with guest speakers was valuable to me.	100
Visiting the diversified organic farm was valuable to me.	100
This learning experience effectively challenged me to think.	92
I liked learning from examples in Indiana. (N = 11)	91
Volunteering at the food pantry was valuable to me.	83
I developed the ability to think in systems thinking way.	75
I think online lessons provided an effective learning experience.	75
Worksheets effectively helped me learn the online lessons.	75
This learning experience gave me skills and techniques directly applicable to my future career.	67

Next, I described students' perceptions and experiences toward specific instructional components. The three main instructional components were: (1) pre- and posttest Applesauce assignments; (2) online lessons with worksheets; and (3) experiential learning activities.

4.6.2 Applesauce Assignments

The Applesauce assignment was originally included in this study as a data collection instrument. However, students perceived the activity to be part of their learning experience regarding systems thinking in the context of sustainable food systems. The pre- and posttest assignments engaged and offered students the opportunity to practice systems thinking especially in terms of making various connections within a food system and with other systems using applesauce as a specific context.

4.6.2.1 Thinking in Systems Thinking Way

As an instructional tool, the Applesauce assignments intended to help students start thinking in a systems thinking way. The assignment engaged Nectarine into identifying and explaining the connections of different parts in a food system along with other systems. From the interview after Nectarine completed the pretest assignment, he felt that there was much more in a food system that he could write about. He shared:

> There is so much that is actually affecting the system. And my tendency is to look at such a small part of it that there's so much more that I am not seeing. And if I spent more time, I would probably come up with more things.

Nectarine ran into a minor challenge when he needed some time to think about the connections between concepts that he did not usually thought of them together. Eventually, he realized how those concepts were connected. This showed that he had to put a lot of thought into this assignment and the assignment engaged him in making those connections. He stated:

> I wondered how production and distribution related to growing apples. I mean I did come up with the trees had to come from somewhere, so I can…At first, I didn't know what to do with that, but later as I worked through it. I did realize it. The tree has to be produced to grow the apples.

Nectarine recognized that the assignment helped him practice systems thinking, which was not easy but was not too difficult. He said, "I think it's not easy because easy would be just, 'Here's the information. Memorize the information and write down the information.' But I don't think it's unbearably hard. I don't think it's an unachievable obstacle."

Apricot discussed after the pretest Applesauce assignment that the assignment was first unfamiliar and difficult because she had not been asked to think about different parts of a system before. She also shared that she tried to complete the assignment by thinking more intensely into different processes of a food system. Therefore, she recognized that the assignment prompted her to think in a systems thinking way. She said:

> I think it was just putting everything into a new perspective, especially the applesauce. And there were so many things to think about, like the inputs, all these, we never had to think about that before…. People wouldn't think about the work that had to be put into growing the tree and then getting the apple and then processing it. So, that was hard with this—thinking about all of it. And that's because there're so many different aspects in the whole thing…. [First it was a little difficult] because I've never done that before. Like I've never had to think about where things started and ended. Once you open up your mind to it, it's a lot easier. I mean, once you actually take time to realize that people have to grow the tree and it's not as hard.

Jujube discussed about her thought process when she engaged in the pretest assignment. She shared, “Once I was able to connect the two, I basically ask the question like, ‘what are the inputs of growing apples, what are the inputs of processing apple.’ I sort of did that for all the charts here.” Jujube pointed out that she had some ideas of how the applesauce is processed, but not in great details. She recalled that as she worked through completing the assignment, she thought of more components that were relevant to the food system of applesauce that she had not thought of before. She said:

> Not knowing the very tiny details of what goes in the applesauce makes it challenging. But just knowing that [applesauce] comes from apples and then apples are then mushed up into a sauce, sort of help. But the more you look into it, there’s other factors of it. Like the tools they use or the machine they use to make applesauce.

Jujube shared that the posttest assignment was much easier than the pretest one. It was possible that she was used to the strategy she came up with for the previous assignment or she was more familiar with coming up with answers on her own after the lessons. She said, “Before [the learning experience], it was really hard. But then after [the learning experience], I was able to answer everything pretty easily. And I was able to put down something for each box after the lesson.”

4.6.2.2 Completing the Assignments

Students were asked to complete the pretest Applesauce assignment after I met them for the first time. For the public school classroom, students were talking and walking around after the bell rang until the classroom teacher told the class to sit down and be quiet. After students received the Applesauce assignment, I told them about the instruction of the assignment and the definition of systems thinking (see Appendix D). I noticed that some of students were confused. Therefore, I started talking to the class that apples had to come from somewhere and needed some people to grow and to transport them. A few students contributed to the discussion while I drew and wrote on the whiteboard. There was a drawing of a seed or a graft becoming a tree and apples on the tree. Then, I pointed out that there were several examples about processing applesauce on the assignment. Students and I also discussed about plastic cups that contained applesauce and the recycling process afterwards. I then let students work on their own. I observed students asking each other about ingredients needed to process applesauce. Students were concerned about being correct. Before the bell rang, the teacher told the class to turn in the assignment. The following Monday, the pretest assignment was handed back to students to finish it. There were a wide range of students with effort and attention. Some students were distracted and talked to each other about other things. A few students did not continue working on the assignment and left the second page blank when they turned in.

The posttest Applesauce assignment was given to students after the final online lesson. It was an activity day, so the class period was 25 minutes. After receiving the assignment, students took a few minutes before getting settled. They started working when the teacher told them to. I allowed students to work together, if they wanted. I just observed. Because the class did not meet the day before and would not meet the day after, there were a lot of small talks among students and between students and the teacher. Some students handed the assignment back after 10 minutes and I got them all back after 15 minutes.

For the homeschool student, I met with Nectarine and his mother in a quiet graduate student office space. After giving him the instruction of the Applesauce assignment and explaining about systems thinking like what I did in the classroom, I let Nectarine work and moved away to sit down at my desk. The whole area was quiet. Nectarine spent approximately 20 minutes and he turned the completed assignment in. I met with his mother after he finished the final lesson and gave her the posttest assignment. Nectarine completed it and gave it to me when we met for the posttest interview.

Nectarine provided lengthy responses on the Applesauce assignments both pre- and posttest. He made various connections and saw parts interacting with each other in a food system. During the pretest interview, he told me that the complexity of a food system and the number of possible responses overwhelmed him and made him feel that he had not completed the assignment. He shared:

> Over time I started to get into kind of a rut because I kind of got tired and zoned out a little bit. So, I was only thinking the same thoughts over again. I think if I went home and slept and came back and did it again, I'd probably have a lot of the same ones, but also a bunch of different ones. Because like I said, systems are all connected.

After the learning experience, Nectarine reported that he changed his strategy into responding to each category provided on the diagram as shown in the example and found the Applesauce assignment to be a lot easier. This showed that a given structure could help students organize their thoughts to help them demonstrate systems thinking. He said:

> I think last time I didn't do how, like, the format you wanted me to so I tried to do it differently this time. I think it was a little bit easier, actually quite a bit easier this time. Yeah, it wasn't really that too hard.

However, having a structure on the diagram limited how much a student could make connections and demonstrate systems thinking. On the pretest assignment, Nectarine wrote about spatial dimension (see section 4.5.3.2), temporal dimension (see section 4.5.3.3), and systems' changeability (see section 4.5.2.1), which were not a provided category on the diagram. Upon using the provided structure, Nectarine did not identify those aspects on the posttest assignment.

Apricot identified various components on both assignments, but did not provide a lengthy explanation for all her responses. During the posttest interview, Apricot indicated that the Applesauce assignment was her least favorite activity of the learning experience. Despite liking the opportunity to make a lot of connections, she was exhausted thinking and writing them down. She said, "There was a lot of components that I had to think about. And while my brain might have liked it, I didn't. My brain got a good exercise, but there was just so many forms to fill out." This also explained the reason she identified various components, but provided limited explanations discussed earlier in *Section 4.5.1*. It could also be interpreted that the activity was problematic and not engaging to students who did not like writing.

Jujube made limited connections and explanations on both assignments but verbally demonstrated systems thinking during the interviews. During the posttest interview, Jujube revealed that she was concerned about getting the answers right. This also showed that she was not used to coming up with answers on her own. She suggested that more information should have been provided on food production and processing while consuming was easier because it was more relevant to her as a consumer. She said:

> I think maybe a little more information on how apples are produced. Because even though most of us know where applesauce comes from, we just automatically think that apples just go through, they mush some up, and then they are put in containers. When it could be much more different than what we think…. The consuming part, I thought that was easy in my opinion, I guess. Because we're the ones who are consuming the applesauce. And we know what to do in order to consume applesauce.

Based on the Applesauce assignments alone, Jujube did not meet an expectation of identifying and explaining about various connections. However, she was able to describe and elaborate those relationships within a system and between systems verbally. This suggested that completing the table might not be an appropriate format for Jujube. Narrating or writing an essay might capture more elaborative responses for her.

Kiwi completed only half of the pretest assignment. He told me he was confused. He said, “I just didn’t understand how to do it. I just didn’t quite get it there for the first couple minutes. I don’t know what are we talking about here.” He said during the interview that he now understood despite completing only half of the assignment. I then asked what could have been helpful to him. He said, “I guess directions on how we first did it or examples.” This showed that a new strategy would be needed to demonstrate what students were expected to do. Explaining to the class while having all students making several connections to complete a table cell together could potentially provide a good example for a first step.

After the learning experience, Kiwi filled in all the spaces for answers, but he provided a few components and with limited explanations on the posttest assignment. Therefore, I asked him to tell me more about applesauce verbally. He had some knowledge about growing apples and processing applesauce. He explained to me step-by-step about what he witnessed from an old-fashioned applesauce making process. He did not seem to understand that he was expected to use what he already knew in completing the assignment. I then asked him about packaging. He said, “Like school, I know the cups you're talking about, but I don't know how factories produced them and then put them in the cups.” He was able to talk about landfill in addition to that. The format of the Applesauce assignment might have worked better for Kiwi if he was required to respond verbally to prompts. However, it might be more difficult to determine whether Kiwi could initiate those connections on his own as what was expected from systems thinkers because he needed to be asked constantly to explain each connection. This could also show that the Applesauce assignment did not work well for students who were not a systems thinker.

Blueberry did not provide various components on either of the assignments. After the pretest assignment, Blueberry stated that the assignment and the diagram were confusing. He thought the questions were redundant. He said, “It was kind of confusing but kinda not. Just locating things. It just was asking the same questions on the different pages. I did [look at the diagram]. It was confusing." He did not think the topic *inputs* and *human health and well-being* were different.

After the learning experience, Blueberry wrote about different processes of a food system in a step-by-step manner, which aligned with what he understood about systems thinking. He thought that a system was connected by one thing happened after the other or an item went from a place to another place. He also viewed a system as a separate entity that had a clear boundary (see section 4.5.1) with a single disciplinary perspective (see section 4.5.3). Blueberry would benefit from a thorough explanation and more examples of what was expected of him on this assignment. Understanding the assignment better might eventually help Blueberry change systematic thinking to systems thinking.

Raspberry had trouble completing either of the assignments. She was unable to complete the pretest assignment and wrote "I don't know" and question marks on several table cells. She found it difficult for her to explain because she did not have a direct experience or knowledge in processing applesauce. She said she could respond to growing apples and consuming apples. She would be more comfortable if she was an apple producer and applesauce maker. However, based on the observation, she did not identify or explain well in this assignment in neither of the three processes. She said:

> Explaining it [was challenging]. And how like everything goes into it or leading into it. And I think the most challenging part was mainly…but sometimes doing the process because most of them I did not know the process too and breaking it down. Like I have more of a better choice of growing apples to consuming apples. I would have been much better if I was like on an apple farm or something. Like, how that can help and I'm producing and like actually making applesauce.

On the posttest assignment, she was able to identify some components on the assignment without giving detailed explanations. During the posttest interview, I asked her to walk me through her responses on the assignment. She still indicated that she did not have sufficient knowledge to respond to my questions about applesauce or make connections between processes and components. She also had trouble with pronunciation or using certain vocabulary to explain. She even said sunlight is important for processing applesauce by providing vitamins. Examples of how she organized her thoughts are as followed:

> For the environmental impacts, when growing apples, you have to be careful of how cars and the smoke of pollution can affect the environment on your crops and

> how it affects the waste management and the air to it. And then the influences, not everyone would believe in having culture of growing apples and also depending on environment with their soil or either or what they're raised as, born to like either raised them. And then outputs of growing apples, I don't know if I answered that correctly, but I said pollution slash waste management can affect the outputs of how the results of the products that is produced. If it was either good or bad in a way. And then pressing applesauce for the environmental impacts. So, if the soil is more healthier, the healthier the product and income would be safer to eat. And also, the processing of applesauce, for influences, show like, the more research or results you have, you have more of in which helps progress the progress more.

Raspberry might need to be taught about systems thinking using other contexts with a simpler system. A food system might be too complex to be her starting point. She also needed a mentor to help her identify components and make connections between those components.

4.6.2.3 The Context

The assignment instructed students to explain how the life cycle of applesauce from growing an apple tree until throwing away a container is relevant to different dimensions of food systems. Applesauce was chosen as a specific context because it is a commonly known and eaten food item in the United States. It was anticipated that students would find applesauce to be a relatable food item. Overall, students in this study showed that they had the basic knowledge about applesauce. Jujube pointed out that she had a general idea about applesauce. But she said, "Not knowing the very tiny details of what goes in the applesauce makes [the assignment] challenging." However, after taking more time to complete the assignment, she said, "But the more you look into it, there're other factors of it."

During the pretest interview, Blueberry stated that the assignment and the diagram were confusing. He felt that the questions were redundant. I then asked if he would find it easier to complete the assignment with other food items he was more familiar with, such as steak that he chose to talk about earlier on in the interview. He refused because he thought the assignment would still be at the same level of difficulty.

Raspberry struggled with the assignment. Therefore, during the pretest interview, I asked Raspberry to choose another food that she was more comfortable with. She chose tomatoes due to her direct experience in growing tomatoes and making salsa. Then, she tried to explain each topic on the diagram in place for applesauce. She said:

> I'd probably do mainly tomatoes because I have more of a background of tomatoes [and] making salsa as well. And, that is much easier than applesauce personally, that's what I would think. For salsa, for this production and distributition [distribution], the way you package them, you have to be more delicate with the tomatoes, mush. So, for like marketing could be an example if you're selling them at the farmers' market or just general. [In terms of environmental impacts], for salsa, water or the healthy [health] of the soil can affect the tomato in which like water can also of rot the tomato and damage it. And then, the soil depending on the type of soil that you use, can also affect in a way like damage or like the flavor of salsa. For the waste, there's not that much to waste out of it really coz you pretty much is using the whole tomatoes to make it that way. So, there's not much waste when processing the salsa. You try to use the whole tomato.

Despite using a context that she was more relatable than applesauce, Raspberry did not demonstrate the ability to identify various components and make connections during her verbal explanation.

4.6.2.4 Research Data Sources

From the research standpoint, the outcomes of this assignment were useful in analyzing how students demonstrated systems thinking in terms of recognizing different parts of a food system and showing how components, processes, and other systems (i.e., health and environment) were related to a food system. The outcomes were divided into three categories.

First, the assignments provided an opportunity for students to demonstrate systems thinking through written responses. Specifically, Nectarine and Jalapeño provided various components and various relationships within a food system and with other systems (see section 4.5.1). In addition, the two students wrote about the nature and behaviors of a system (see section 4.5.2) as well as how a food system could be related to time and space (see section 4.5.3).

Second, the assignments served as a structure for students to demonstrate systems thinking verbally. Specifically, Apricot and Jujube did not provide elaborative responses on the assignment. During the interviews, the assignments were used as a prompt in asking them to describe a system (see section 4.5.1), discuss about the nature and behaviors of a system (see section 4.5.2), and explain about how they viewed a system (see section 4.5.3).

Lastly, the assignments indicated the lack of abilities to demonstrate systems thinking. For two interviewees, Blueberry and Kiwi, they wrote step-by-step events about how the apples traveled and became applesauce. The type of thinking that Blueberry and Kiwi demonstrated was systematic thinking. Another interviewee, Raspberry, could not complete the assignments and could not verbally describe components, processes, and relationships within a system and between other systems. Other five study participants also wrote down a few components for each table cell with limited explanations, which could indicate that they could not demonstrate systems thinking.

4.6.3 Online Lessons and Worksheets

Ten self-directed online lessons about sustainable food systems were designed for students to take control of their learning pace. The instructional content in each lesson were presented in the formats of readings, slideshows, audio files, and videos. A worksheet was designed to engage and help students understand each lesson and stimulate the practice of systems thinking. The questions on the worksheets encouraged students to come up with their own answers rather than merely repeating the information provided on the lessons. For example, students were asked to discuss how a 2-hour delay affected their meals throughout the day; define the boundary of what they considered local; respond why it was important to look at things from a different perspective; and indicate what they as a consumer could do to address climate change (see Appendix G).

Based on the evaluation questionnaire, three quarters of students reported that they thought that the online lessons provided an effective learning experience and the worksheets effectively helped them learn the online lessons. In this section, I described students' experiences and perceptions toward the online lessons and worksheets based on their responses at the bottom of the worksheet to gain insights from all students regarding what they found useful about each lesson and what they thought could be improved for the lesson as a formative assessment and the interviews from the six students as a summative assessment.

4.6.3.1 Format and Organization

The online lessons were presented on a website with one lesson per one webpage. The worksheets for each lesson were printed on paper. As a homeschool student, Nectarine tended to have different experiences in terms of the format and learning pace from other study participants in the public school. He shared with me that he had previously participated in a video curriculum where he learned materials by watching recorded lectures. In addition, he was also responsible for a list of daily tasks. He moved on to the next subject whenever he finished the work instead of waiting for a class period to end. Therefore, Nectarine seemed to be comfortable with the format of the online lessons and taking initiative of his own learning pace of the sustainable food systems learning experience.

Although Nectarine was familiar with the on-screen format, he had a small complaint about his eyes not feeling comfortable staring at the screen for a long time. He said:

> Not really know that I had a least favorite, maybe the work, the worksheets. But that's just coz sometimes after I look at a screen for too long, my eyes start hurting. So really there was nothing wrong with the program, I don't think.

Nectarine did not have any comments on what could be improved on the lessons and worksheets. Other students provided the feedback for the lessons and worksheets on more detailed directions to navigate the lessons and to help complete the worksheets, examples for students to model after, and the length and pace of the lessons. Jujube wrote, "[The first lesson could be improved with] more detailed direction. [The second lesson could be improved with] more description. [The fifth lesson could be improved with] more examples." She also said, "Another thing that would have been helpful was to add more examples and have us make our own examples based off of the example you gave us." Blueberry wrote, "[The first lesson could] be more laid out and more navigationable, more organized. [The second lesson could be improved with] navigation on [the] website. [The sixth lesson could] have the first part more laid out. [The tenth lesson] went too fast." Arugula wrote, "[To improve the first lesson,] maybe [provide] more examples to help." Edamame wrote, "[The first lesson could be] not as long." Kale wrote, "[The second lesson could be] easier to follow, better instruction."

After receiving students' formative feedback, more detailed directions were provided for both the lessons and the worksheets. The worksheets for the first to the sixth lessons each had three pages. After getting the feedback, the worksheets for the seventh to the tenth lessons each were shorten to two pages. The lessons were shorter as well. Most students seemed to like the improvement and wrote, "Nothing [needs to be improved]" for the seventh to tenth lessons. Apricot wrote, "[The sixth lesson] was nice and easy to understand." Blueberry wrote, "Very straightforward worksheet. [The seventh lesson is] pretty well this time. No improvement [is needed]. [The ninth lesson is] pretty straightforward."

Kiwi shared that early on, he struggled with finding answers. He shared, "[The online lessons] were a bit confusing. There was some stuff I just couldn't find, so I just wrote random answers on. Like I took a guess coz I couldn't find them on or through the video." After a while, he gathered that the answers were not provided. He said, "I just kind of took what I knew and wrote it down." He suggested to me that "more detailed directions" could have helped improving the confusion for him. I pointed out that the lessons provided written instructions and examples. However, he did not think those were sufficient. He said, "Well, they were specific but I still got confused on some things"

For video lectures, some students found them useful, but some students did not like the video format. Apricot thought that the videos were informative and the examples were helpful for the learning. She said, "The videos were really informative. But this time the stuff on the website was informative as well. And the examples and stuff on the computer, it was all nice way to learn." When I asked Blueberry about his least favorite part of the learning experience, he said, "I don't know. Probably just watching the videos online. I'd rather just read it and do it." Blueberry wrote, "[The third lesson could be improved by having] less videos. [The tenth lesson has] a good video." Blueberry pointed out that the last video was an exception. Blueberry said, "[The one about food pantry and community garden] was cool. Like what they do and the causes they were trying to do. That video was good. But just the others." The last video was the shortest and was designed to be less like a video lecture because of the background music and transitions. It was produced after I received feedbacks from the participating students.

Other students did not prefer the video format. Arugula wrote, "[The fourth lesson could be improved by having] less videos." Raspberry wrote, "[For the sixth lesson,] I found it more useful/helpful with today's activity with more pictures/examples/texts to read to help me understand more instead of videos." In addition, Raspberry did not like learning through the computer. She preferred learning with note taking, class lecture, and class discussions. She recognized that interactive learning and field trips were helpful to her learning experience. It could be implied that Raspberry prioritized getting answers correctly as her priority of learning. She said:

> Personally for me, I don’t do well with online sites. I would rather have the paper and do notes on or written notes in class. It would be more talking in front of the class obviously with this and more activities probably interactive learning. I would have personally enjoyed more class discussions and hands-on activities. I know you kind of provide that as well with the field trips and stuff like that, which helped, which was really nice. And like the voice video call with [a farmer] was helpful with answering questions.

Raspberry did not seem to be aware that the answers were not always provided on the lessons and she seemed to struggle with completing the worksheets when she did not find the answers on the materials. After I improved the lessons by providing a summary for the videos, she found the text to be useful. She said:

> I can get through the website pretty easy, but finding some information was a little bit difficult. And other times some of it is really clear to the point. Depending on the question, for example, biodiversity, examples of that was kind of easy. Another one was waste management like that, or like food system, like examples of those. Those were easy to find. But other ones like in videos for me personally, it’s a lot harder for me to find the answers to. But if sometimes like in script, more details, then I can find it more easier. Sometimes I just use my resources and my knowledge or getting more details like search out more facts.

Finally, Apricot talked about the class motivation that she observed. She commented on students that did not put a lot of thought into the learning because they lacked of willingness. She said:

> Unfortunately, the class that you were with had students that were unwilling to do what you were asking them to do. Some of them didn't want to think about it and this program made all of us think about it. But I don't think there's anything that you could've done to the program to get better results from certain kids because they just didn't want to.

She suggested that more interactive components could be added for students on the website to motivate them to do more. She said:

> Maybe on the websites, if you can do like more things to interact with on the websites. That kind of sounds like that's a lot of work for you. But I feel like you would get the kids that aren't willing to sit down, read through all of it. I think you would get them to want to do it more.

4.6.3.2 Self-Directed Learning

The lessons were designed to be self-directed by the learners. For Nectarine, the mother who served as the homeschool teacher reported that he did not have difficulty using the online lessons and seemed to enjoy learning about this sustainable food systems topic. Nectarine and his mother set up a goal to complete the online lessons within four weeks. I had two one-on-one discussions with Nectarine during the curriculum about the progress, possible challenges, or assistance he might need. He reported that he did not have trouble navigating or understanding the lessons. He admitted that occasionally he had to pay closer attention by rereading the directions before completing the activities on the worksheets. Nectarine fully took control of his learning pace. He agreed that the self-directed format worked well for him. He said, “I watched the videos, then I answered the questions. I think it was pretty much you could find the information that you needed in the lesson. So, I don't think [a facilitator] was necessarily necessary.” Nectarine’s thorough responses on the worksheets showed he was highly engaged with the lessons and successfully met the learning objectives.

For the public school classroom, I observed the first and the second class when students were learning the first lesson of the sustainable food systems learning experience about components and relationships in a food system. I noticed that most students focused on completing the worksheet and did not explore other elements on the webpage, which were part of the lesson. A lot of students were distracted. They talked to each other about other things besides what they were working on. Students spent time longer time than expected in finishing the worksheet. Therefore, it took approximately two periods to finish one lesson.

Some students in the classroom reported that they needed some help and guidance from the teacher. During the first few lessons, the classroom teacher let students navigate the lessons on their own. Then, the teacher noticed that some students needed some structure because they had difficulty paying attention when being allowed to work independently. A few students talked loudly, which distracted their classmates. The teacher then decided to control of the pace by having the class watch the videos together on a big screen, instead of on the individual screen. Raspberry reported, “[The teacher] tells us instructions on what to do in class. There were a few times we watched one of the videos together and then discussed over it help as well.” However, the teacher facilitating the learning pace was not sufficient for Raspberry. Although, Raspberry put a lot of effort into completing the worksheets, she often copied the information on the lesson to respond to the questions that asked for personal opinions or for students to generate new ideas. This might be preventable if she received an immediate feedback on her worksheets.

Raspberry was not the only student who was not used to the setup and format that encouraged students to come up with their own answers instead of regurgitating the provided information. Kiwi wrote, “[The second lesson] needs [to be] taught, not just given. [The third lesson,] I don’t know. It was purdy easy.” However, on the third lesson, Kiwi copied answers from the lesson without generating new ideas intended by the activity. He later admitted that it did not work out later on. He said, “I kind of started figuring that [the answers were not provided] throughout the ones. I just kind of took what I knew and wrote it down.” Kiwi also reported that he did not ask for the teacher’s help. He said, “[The teacher] helped other people but I didn't ask for it…. Nay, [it wouldn’t have been better if she helped.]” Kiwi thought that more detailed directions would have been sufficient to make the experience less confusing. Kiwi’s engagement on the lessons was inconsistent. He provided limited explanation for his responses and did not meet the expectation.

Jujube was confused about what was expected of her until the teacher explained to her about the expectation and then she was able to work on the lessons on her own. Jujube wrote, “[The fifth lesson, it was useful] having the teacher go through this with us.” During the interview, she said:

> I do need help at the beginning on how to start it. Like what the packets [were] about and where are we exactly supposed to write down for the general questions and everything. But I'm usually able to do it by myself…. I think [having a teacher] was helpful. I struggled with some parts with finding directions and knowing what to write down. But after I was talked through what I'm supposed to write down, it got easier.

Jujube then said that she needed more time to think and come up with her own answers because the questions needed to be interpreted and the answers were not provided. A majority of her worksheets showed that she successfully engaged with the lessons and provided elaborative responses. She said:

> Some of the written responses on the videos were hard to get because sometimes the information wasn't direct. It's more of like you have to interpret what they were saying…. It wasn't that overwhelming. If I were to be given the lesson again, I could probably do it on my own with a large amount of time, I guess, to find and interpret those answers.

At first, Apricot was unfamiliar with the instructional design and confused by the worksheet. She wrote a comment for the first lesson about what could be improved. She wrote, "[The first lesson] needs to be explained further beyond just a packet." However, she adapted to the self-learning format. A majority of her worksheets showed that she successfully engaged with the lessons and provided elaborative responses. When being asked if a teacher's help was necessary, she said the lessons provided what she needed to answer the questions. She thought that a teacher might be helpful for unmotivated students. She said:

> [The teacher was] showing us the videos, [that] is all. If we had questions, she explained it. I didn't really need her. The kids that didn't try definitely needed her because they weren't willing to sit down and look at what you did for them. They're just wanting to know the answers to the packet without finding it for themselves. So, they needed her. But the people that were more motivated to do it got all the answers from the computer.

Apricot added that sometimes she did not feel motivated to come up with her own answers, which made the self-learning format became difficult. She said:

> It was really unique. I've never done something that actually challenged me to think so much. Like I couldn't get the answers from online. I had to think about them. So, it was really cool. It was definitely a unique way of learning, but it was effective…. Thinking outside the box sometimes when I didn't have [the] motivation to think outside the box was difficult. But once I'd done that, it was fine.

Finally, Blueberry said, "[The online lessons] were pretty straightforward." He did not feel that he needed help from the teacher. For the online lessons and the worksheets, he said, "I felt like it was self-explanatory from the papers and the online." Blueberry's engagement on the lessons was inconsistent. He showed great effort but he did not always provide a thorough explanation for his responses.

4.6.3.3 Content Knowledge

The online lessons and worksheets provided the opportunities for students to practice systems thinking and learned about the sustainable food systems as the context. In terms of practicing systems thinking, Nectarine, who demonstrated systems thinking throughout the study, indicated that thinking in a systems thinking way was not new to him. He commented on how the lessons strengthened his thinking about connections of different parts as well as a bigger picture of a system. The lessons gave him more information and specificity that supported his thinking of a sustainable food system. He shared:

> Just being able to think about all the different parts. Like it kind of elaborated and solidified the ideas in my mind. I knew that it's complicated and there's different places, different things and restaurants are wasting food. But this was able to help quantify up more and be more of a teacher. Like, you can buy fact or get fact books from the library, but it's different from actually learning about, like say, you get an animal fact book about all the different types of animals. That's different from learning about each animal individually and their specific habitats. This is, I would say, this is more information and more helpful than just thinking…. It's more bigger picture. So, you have done the work to bring together more information than I could just sit down and think of myself.

In terms of the work that Nectarine put into learning, Nectarine acknowledged that some lessons required more thinking and he considered those lessons to be more difficult. He said, “Because they were a little bit longer, it kind of depended on how long it took me. So, the one was easy for me and then the others were a little bit more thinking a little bit harder.”

Apricot discussed about how the lessons were different from her previous learning experiences and how they encouraged her into thinking more deeply about what to respond. She found the method to be effective and enjoyable. She said:

> It was really unique. I've never done something that actually challenged me to think so much. Like I couldn't get the answers from online. I had to think about them. So, it was really cool. It was definitely a unique way of learning, but it was effective…. I really enjoyed this. I've never been made to think about something. And [this program] makes you think a lot more and I really liked it.

Jujube’s comment could also be implied that she recognized that she had to think about the questions and the responses to engage with the lessons. She said, “Some of the written responses on the videos were hard to get because sometimes the information wasn't direct. It's more of like you have to interpret what they were saying.”

Kiwi, who did not demonstrate systems thinking in this study, admitted that thinking about food as a system, a cyclic nature of a food system, and natural practices in farming was new to him. Initially, Kiwi told me that he already knew most of the knowledge about food and agriculture presented in the lessons by learning from his family members. He said, “Coming from a farming family, most of the stuff we learned, since my grandfather's been farming since the late sixties, fifties. So really everything we learned, he's already taught me." He added that his uncle had a food manufacturing job and told him about food processing and factories. Other terms such as *climate change* and *biodiversity* he learned them in biology, although he could not explain what they meant to me. It would be crucial for Kiwi to understand that making connections and viewing food as a system were concepts that he learned from the lessons besides learning about facts and definitions.

In terms of the sustainable food systems context, in general, Jujube seemed to like the topics that were taught. She said, "I'm not sure if I had a least favorite because I really enjoyed a lot of the lessons." Similarly, Nectarine was highly motivated because he liked learning. He said, "I think I enjoyed all of it to a fair degree…. But I really do like learning about this kind of thing. I really like learning, so any kind of learning is fun for me." Nectarine commented that some lessons had a topic that he liked and he got the work done quickly. He said:

> That one [the lesson about key players] was interesting and I really liked—I actually like beekeeping. I tried twice and I failed both times, but I still enjoy the experience. So, I really liked this one. And so, it was interesting that [I] got it done pretty quickly. And then I moved on to this one [the lesson about influencing forces] because I figured I could do another one because this one didn't feel like very much work to me.

Apricot learned about the variety of food available in the local area, she wrote, "I did not know that we could plant some of the food John [the seed saver and farmer] talked about here. During the interview, she said:

> I didn't even know we grew that much here in like-- I know we grow, you know, like corn and soybeans. I just never thought that we have so many local farmers. And I thought all the food that we got from restaurants was all like processing, like all the vegetables. I never thought any of them are fresh. But now that I know that some of our restaurants get them from local farmers. I didn't even know we had like a bunch of local [vegetables] farmers. I thought it was all cattle.

Nectarine also commented about what he learned from Farmer John. He wrote, "John was interesting and what he does fascinates me." During the interview, he said:

> John did the heirloom variety. So, if he had heirloom apples, that is one way that growing apples, that's one benefit of them as you can—if you choose to grow different apples, it can benefit the environment in different ways and it can be more resistant to different diseases. So, that was very interesting to learn about. Like that was my favorite episode.

Students' responses expressing what they found useful learning about systems thinking in the context of sustainable food systems could indicate their focus on what was taught. For the first lesson about a whole system and its components, some students commented on learning about the relationships of the whole system, which is systems thinking. Apricot wrote, "It made us think further into how things in the food industry are done." Jalapeño wrote, "Knowing how everything is related to each other." Nectarine wrote, "It is helpful to think about systems in a different way." Some students commented on learning about focusing on some parts or aspects of the system, which is reductionistic thinking. Blueberry wrote, "It teaches you the importance of each process to get the food [to] the consumers. Arugula, wrote "Learning what things have to go through." Edamame wrote, "[It teaches us about] all the time and effort."

For the second lesson about levels of food systems, Apricot and Jalapeño recognized that the activity tried to engage students to learn about other perspectives. She wrote, [It's useful] getting to see other people's opinion on what they consider local." Jalapeño wrote, "[I learned the] need to support our local farmers to help keep things balanced."

For the third lesson about interactions between systems, most students commented on the activities from different systems they learned through a short video about transporting eggs. Apricot wrote, "[It's useful] thinking in depth about the oil/gas, pollution in just boiling an egg." Nectarine wrote, "It is helpful to think of how all the systems are interconnected." Jalapeño wrote, "[It's useful] being more thoughtful when using energy." Kale wrote, "[It's useful to think] about how far an egg will travel before it gets to the store."

For the fourth lesson about different actors in a food system, students recognized the importance to recognize other people's jobs and their perspectives. Jujube wrote, "[It's useful to learn about] the different perspectives of other jobs and what it's like for them." Jalapeño, "[It's useful learning about] the hardship people have to go through." Nectarine wrote, "[It's useful] to realize how many actors there are in a food system." Raspberry wrote, "[I] found it useful leaning how many different actors can be part of the food system."

For the fifth lesson about the variables affecting on or being affected by a food system, students compared different situations for different families around the world. Raspberry wrote, "I thought it was useful to compare the prices and foods from different countries." Blueberry, "[I] found out what other countries eat." Apricot wrote, "[It's useful] thinking about other families all over the world."

For the sixth lesson about the impact of food systems, students learned about stock and flow diagram which addressed inputs and outputs into and out of a food system. Nectarine wrote, "It is useful to understand how everything flows through a system." Blueberry wrote, "[I] learned about stock [and] flow." However, Edamame, Kale, and Spinach wrote, "Nothing [was useful].

The other four lessons focusing on a specific topic as a case study. Students learned about food waste; climate and biodiversity; sustainable practices for consumers and citizens; and community garden and food pantry. Their comments were toward the technical content of the lessons rather than the concepts directly related to systems thinking.

Lastly, there were two suggestions about more examples that could be added to help students understand the materials better. Blueberry commented that he would like "a boarder range" of examples to be applicable to his situation because he would be moving out of Indiana. Nectarine made a comment suggesting about adding more facts into the lesson. He wrote, "I am not sure that climate change is really a problem." Then, he talked more during the interview. He said:

> I think a little bit more information would be a little bit nice. I know you're trying to keep the lessons on short, but maybe a few more. I like to research and study things before I just be like, that's a big problem. So, I think that's another reason. Like [the lesson] was presented this, and I've heard a lot about it on the news, like this is a huge, big problem, but nowhere have I really seen like information. Is there another explanation?

4.6.4 Experiential Learning Activities

For the sustainable food systems learning experience used in this study, students met with and got to ask questions from four guest speakers who were knowledgeable about food systems: an urban farmer, a seed saver, a food systems professor and researcher, and a diversified organic farmer. The guest speakers provided insights on sustainable food systems in the local area. Students also went on field trips and participated in hands-on activities (i.e., volunteering at a food pantry, using reusable tableware during lunch, visiting a university student farm, visiting a diversified organic farm, and planting seedlings). Based on the evaluation questionnaire, all students reported that interacting with guest speakers and visiting the diversified organic farm were valuable to them. For volunteering at the food pantry, 83% of the students reported that the experience was valuable to them.

Initially, the program planned to assign the participants with a presentation after the field trips to share what they learned overall from the sustainable food systems learning experience. However, the time spent on the lessons was longer than planned and the presentation did not fit in with the school schedule. Therefore, the presentation was not assigned. The data regarding students' experiences and perceptions toward the experiential learning activities were mainly described based on the posttest interview. The interviewees had positive experiences doing hand-on activities on the farms in terms of reinforcing the existing idea and concepts taught in class, witnessing real-world examples, and applying the experiences in future projects. Additionally, the interviewees enthusiastically shared the knowledge gained from the trips.

First, I described Nectarine's experiences and perceptions. He enjoyed visiting farmers on their farms and seeing non-traditional methods. Nectarine benefited from the first-hand experience of the real-world practical examples, which reinforced what he personally valued as discussed in other sections previously. He said:

> I really enjoy the field trips to see the farmers. So, I liked actually being able to get out and see what they are doing and the idea of how they operate a farm without using chemicals and without using traditional large-scale methods. That was interesting.

Nectarine also said he would use what he learned from the field trips, which showed him the possibility for a small farm. He planned to have a small labor-intensive operation planting specialty crops and using a direct-to-customer method in the future. He shared:

> I'd like to farm, but I don't want to just have a connection to what I'm farming. Like, I like plants, but I don't just want to sit in a tractor all day driving around fields and just see them. I want to touch them and digging in the soil with my hands. And the produce, [the] student farm has shown that you can actually do that. You don't make a living with less farm than that. So, I think what that meant is, if I'm going to be a farmer and if I choose to do that, then I'm not gonna go spend however much money trying to buy a big farm. I'm gonna buy a couple acres and then grow products that will sell for a lot of money. And some just direct to consumer. And do it that way because I think that's more profitable. Like if I chose how I made my money, I wouldn't farm thousands of acres. I'll farm a few acres but still maybe make the same amount of money.

Second, I described Apricot's experiences and perceptions. Apricot enjoyed having the first-hand experience after learning from the lessons. She shared that her previous learning experiences had been using rote memorization or fact recall strategies, while the field trips went beyond those strategies and allowed her to visit an actual site, learn by doing, and have a lot of thinking exercises. She said:

> I really enjoyed this. I've never been made to think about something. I've always just learned it, memorized it, and then moved on. Then I've never actually had to do something about it or go and see what we were learning about. And [this program] makes you think a lot more and I really liked it.

Apricot elaborated on new things she witnessed and learned regarding gardening and small farm operations. She also recalled her involvement in the hands-on activities, which she liked. She said:

> The field trips were really hands-on. I really like those. I got to learn a lot about gardening and stuff and it was stuff that I hadn't thought about. Like how they're only using small, the small land. They own small plots of land to make the most and they're making the most out of it. That was really cool. And I had to see that. And so that was probably one of my favorite parts. [The diversified organic farm] was the most informative, but they were both fun.

She reported that she transferred what she learned on the field trips to her garden regarding the seeding technique and increasing diversity. She said:

> A lot of the farming stuff I didn't know. Like the smaller [the] seed, the less you put it in the soil. Like it doesn't go as deep. And when we did our garden, we planted all of our little lettuces way too close and they didn't have enough nutrients and they kind of just died off one strain of them. But I also learned that you have to plant in different strains in case they catch them diseases. We have three strains of lettuce in our own garden and then we had like flowers to keep it diverse. We had onions and cucumbers and stuff.

Third, I described Jujube's experiences and perceptions. Jujube had a good experience with the field trips. She also summarized how different instructional components and different activities worked together to benefit her learning about sustainable food systems topic. She shared:

> I thought [the program] taught me more about food systems, especially toward the end. I learn more about food systems through the field trips and the lessons and that the food system has a big impact on the environment more than what I thought it had…. I think the field trips were very fun and educational. I really liked going out to the farm and everything. And I also liked going to the food pantry, getting in some volunteer hours, and seeing what they do at the food pantry and what they do for the homeless people. I think the online lessons helped

> a lot. It put a lot of background information into the field trips. As we went on the field trips, we knew what we were going to expect and we learned more information off of the background information.

Jujube specified her favorite activity being on the farm. She mentioned her direct experience learning about compost and fertilizer, she also used the experience to discuss about the cyclic nature of a food system (see subsection 4.5.2.2). She said:

> My favorite part, will be going out to the farm and helping plant the kale and all of that. And then learning about the compost. And then learning about how most farmers use organic fertilizer instead of buying fertilizer. Like they use chicken poop or manure for their fertilizers…. I did eat a carrot with manure on it. I mean eventually [food] has to go somewhere. There's always manure and poop in the soil.

Additionally, Jujube had a good experience meeting the guest speakers and discovering the new university farming location. She said:

> The [university] farm out near the golf field that I did not know existed. And now I do know that it exists and it was like a lot of fun too because the people that we interacted with were very fun and energetic.

Fourth, I described Kiwi's experiences and perceptions. Kiwi enjoyed interacting with farmers the most, especially a farmer who had both animals and crops at the diversified farm, which he could relate to as he also raised both animals and crops. Kiwi explained, "[He]'s got the closest farm with what I've got. Except we're a bit bigger than his. It's just, he plants and runs the same animals that we do. Minus the llamas." However, when I asked Kiwi about something new he learned from the farmer. He responded, "No. Grandpa's done it before. Like, he's raised me that way." Kiwi explained his experience. He said:

> [The diversified organic farmer] taught us the natural. Like, he doesn't use any chemicals. He rotates crops and uses different crops close together. So, the insects that eat that crop or the second crop is bringing in the insects to eat that crop or the other crops. So, it kind of cancels those two out instead of using chemicals to kill off the insects and then adding chemicals to the corn. I mean we could try it [at home]. Yeah, I mentioned it to Grandpa. He said he'd think on it. He doesn't want to take the risk, I don't think. We weren't going to use the whole farm. I was thinking a little part of it.

Fifth, I described what Blueberry learned. Blueberry did not discuss about his experiences and perceptions toward the experiential learning activities. However, he mentioned a few things he learned from the field trips. During the discussion about local foods, he said, “We learned that on one of those field trips. A lot of them [farmers] would try to grow like exotic food system for Indiana.” He responded that local means things that are “near you.” He said it helped reduce transportation cost and distance. He said, “[When transporting food], the food can go bad. It can get lost.”

Finally, I described Raspberry’s experiences and perceptions. Raspberry stated that she preferred hands-on activities and interactive learning over the website because it increased her interest. She found the provided experiential learning activities to be useful for her to answer the questions on the worksheets. Raspberry especially enjoyed volunteering at the local food pantry and felt she could relate hands-on activities to her food science class. She said the activities helped her in better understanding the concepts taught in class. She said:

> I like more [of] the hands-on or the interaction. Like for example, when we did [the food pantry], I was interacting more, doing things I would enjoy doing. Like the packing of the pasta that we did and how it could relate to what we were doing in food science. And also, more in-depth about like when we went to the farms. That helped a lot too, understanding more of the concepts of what we were learning.

4.7 Applications and Benefits of Systems Thinking

Based on the analytical framework, two main goals of systems thinking included: (1) to help an individual better understand complex phenomena (Ponto & Linder, 2011); and (2) to support an individual in making decisions to change a system to be more desirable and sustainable (Arnold & Wade, 2015; Bawden, 1991; Ponto & Linder, 2011). This section addressed the third research question to explore how students intended to apply systems thinking beyond the learning experience by describing how students discussed about the benefits and importance of systems thinking, how they could apply systems thinking to better understand complex phenomena, and how they could apply systems thinking that would lead to a more desirable and sustainable system. The data were analyzed from the interview transcripts, students’ worksheet responses, and the feedback questionnaire. An overview of applications and benefits of systems thinking described in the following sections was presented in Table 4.5.

Table 4.5: Summary of Applications and Benefits of Systems Thinking

Systems Thinking Goals	Applications and Benefits of Systems Thinking
Understanding complex phenomena	• Seeing a bigger picture • Understanding influences • Increasing effectiveness and efficiency • Thinking about other complex systems • Understanding other perspectives
Changing for a desirable and sustainable system	• Making desirable food choices/food-related decisions • Reducing environmental impact • Supporting local community and economy

4.7.1 Understanding Complex Phenomena

A systems thinker considers concepts such as multiple interdependencies, consequences, and spatial and temporal factors that are deeper than a simple cause and effect in order to gain insights of a given situation and understand the complex situation (Ponto & Linder, 2011). This section described what students indicated as the benefits of thinking a systems thinking way that could help or have helped them better understand complex phenomena.

First, students discussed about seeing *a bigger picture* of a working system. Nectarine responded about his systems thinking abilities during the posttest interview that he was able to see a bigger picture and how various different parts connected. He said:

> I can a little bit better be able to see a bigger picture. Like, just see the bigger picture, you know, not just like here's this, but see how it connects to different places and different things and how it affects the things around it.

In addition, Nectarine thought about applying systems thinking to help him efficiently prepare for a debate by understanding a bigger picture and different elements of his topic. During the posttest interview, he said:

> I think it'll help me with debate too. Because when I debate, I need to look beyond just what, here's what my opponent says and accepted it's right. And see, well, you know, the government may have done this or it might save this here, but really this is what it's going to happen. Or like, one of the things we'd like to do in debate is say, if this happens, then it's going to lead to this and then it's going to lead to this and then this is going to happen. It's going to do this and it's going to lead to nuclear war, which is just one example of saying if you can connect the different points and see the consequences and see what's affecting what, then it's

> easier to debate because then I can have a better idea of what's really going on and not just what my opponent says is going on.

Kale wrote on his final worksheet which showed that he recognized more than one profession related to the agricultural sector. He wrote, “There are way more than just farmers in the Ag [agriculture] business.” Similarly, Apricot wrote on the worksheet, “It opens eyes up to different jobs related to the food industry and how many people are really employed in the industry of food.” Apricot also indicated a lot of processes that were not usually thought of as a bigger picture of the whole system. During the pretest interview, she said:

> I think it’s just the fact that a lot of us in this class, we haven’t really had to think about-- know where stuff starts and where things end. We haven’t had to think about that at all. And I think it was just putting everything into a new perspective especially like the applesauce. And there were so many things to think about…. People wouldn’t think about the work that had to be put into growing the tree and then getting the apple and then processing it. So, that was hard with this, thinking about all of it. And that’s because there’re so many different aspects in the whole thing.

Second, students recognized that systems thinking helped increase the understanding of *how something could affect or be affected* by other things around it. Arugula acknowledged that as part of a system, if anything changed from a routine, an individual could be affected by that change. She wrote on her feedback questionnaire, “The way you go through your day is a system. If anything changes in your day, you will be affected by it.” Apricot recognized that systems thinking helped make decisions that could affect the outcome. Apricot said during the pretest interview:

> If I want to be a chef, I’d have to know the science behind it all. I’d have to know what I’m buying. If I’m given five different products, I have to be able to look into that and know which one I’d need for my recipe. I’ll have to know where it all started. And that can really affect my outcome.

Kale, who wanted to own a car dealership, wrote on the worksheet that could be implied that he saw the different parts of the car affecting one another and systems thinking was needed to understand the complex system of a car. He wrote, “Working on a car, you use systems thinking.” Nectarine wrote on the feedback questionnaire about the benefit of thinking of the details behind the cause of a problem. He wrote, “Trying to figure what the source of a problem is." During the posttest interview, he elaborated about solving the conflict by figuring out what affected his sibling's emotion and why his sibling might start an argument. He said:

> Being able to think about things as a whole is helpful with whenever I solve a problem. Say, I get [into] an argument with my siblings or two of my siblings have an argument. I can look beyond, he did this, she did that too. Like who-- what really caused the argument more. And I can be understanding because I can say, 'well, you got me mad, but you were upset because you've been gone all day. And you've been working, or you've been at this obligation.' And like, my family doesn't like to go places, so we're all home bodies. And so, I can say, 'well, you were gone all day and you've had all these things that have affected you and you're getting upset at me, but it's not really my fault.' So, I can, or if there's other problems, I can see or try to find us a solution to a problem that's not just conflict.

Jujube, who wanted to be veterinarian, discussed about the importance of seeing things affecting each other could help her diagnose a sick animal. She said:

> [I] sort of have to connect things. Like how did the animal get sick? Did it get a virus? Or like where did the virus come from? And you sort of have to connect things in order to solve it.

Third, students discussed about how thinking in a systems thinking way could *increase effectiveness and efficiency* in performing a task or improving a condition. Jujube and Spinach wrote on the worksheet that seeing things connected to each other made things easier to do and made the process become faster. Ginger's response could be implied that she recognized that seeing things connected to each other help people accomplish their goal. She wrote on the worksheet, "So you can get stuff done." Nectarine thought about a thorough plan to maximize the use of an object for various purposes. He wrote on the worksheet, "Some things can be used for several jobs and can save resources." Apricot discussed about the benefits in improving the environmental degradation and advancing the research. During the pretest interview, she said:

> If you have a good understanding about all this, you can understand other things that start with this. If I want to go into research [to] further the improvement of the environment, which people have to do. Our environment is not really doing well right now. It's kind of on a downhill. You'd have to know about this. And if you want to improve things from the food system, like if you want to improve how our food is processed, and how that's going into the environment, then you'll have to have a good understanding on the whole thing. And you can't just say that you want to change something you don't know what that something is.

Fourth, students discussed about applying systems thinking to *thinking about a complex system in other contexts*. Apricot discussed during the pretest interview about gaining the new understanding of other roles and events. She said:

> You get a new understanding. It's good for you. You start thinking about other things that's not just food, you know. Things that happen. You'll know that you're not the only person. So, you have to think about other people and other things of where thing starts. Just getting a new perspective on thing is beneficial. You understand things a lot better than other people do. Knowledge is power.

During the posttest interview, Apricot admitted that she started to think of other things as a part of a system. She said, "I'm thinking about 'everything'. Like this bracelet. And instead of just food now. Like everything came from somewhere and you don't just go to the store and buy a shirt. It had to start somewhere." Similarly, during the posttest interview, Jujube responded that she thought she could use systems thinking to think of other products that had a system as complex as a food system. She said:

> Probably like clothing and other products besides foods. That would be a system because it goes through similar processes and it doesn't really, even though you can't eat it, but it still goes through that same process. And then once clothes are disposed they're remade in a new clothes.

Finally, students discussed that being prompted to think in a systems thinking way creating an *understanding of other people's perspectives* and opening up a *new perspective*. During the pretest interview, Apricot that systems thinking could be a new perspective that did not occur naturally but need to be asked for. She said:

> Thinking about things. You have to be open mind. Especially when you're learning because there's a lot of things that people don't think about that you have to think about. It's eye opening. You get a new perspective in this class. Especially since a lot of people just eat because that's what they see. They don't think about the science behind it and all or where it started. They don't think about if it's good for them. They just eat it because it tastes good. No one has to think about this if they're not asked to.

Some of students' responses regarding benefits in looking at things from a different perspective included the different ideas and methods to do something. On the worksheet, Arugula wrote, "You see different ways to use it." Ginger wrote, "So you can get different ideas." Jalapeño wrote, "[Looking at things from a different perspective] so you can see what other people think or different ways to do it.” In addition, Jalapeño wrote, “[It’s useful learning about] the hardship people have to go through.” Similarly, Jujube wrote, “To see what other people are going through. [It’s useful to learn about] the different perspectives of other jobs and what it’s like for them.” Nectarine focused on decision making. He wrote, “To help in making the right decision when problems arise.”

4.7.2 Leading to a More Desirable and Sustainable System

Systems thinking should be introduced and promoted because systems thinking is a thinking that supports an individual in making decisions to change a system to be more desirable and sustainable (Arnold & Wade, 2015; Bawden, 1991; Ponto & Linder, 2011). Throughout the study, students discussed about how they could apply systems thinking in different activities. Students reported that they intended to apply systems thinking in making food decisions and taking an action to support a sustainable food system. Students also considered these applications in the economic, social, and environmental dimensions.

In terms of a *desirable food choice*, students reported that they would apply systems thinking in choosing fresh food from the local community where the farmers used natural growing methods. First, I described how some students were concerned about the safety and cleanliness of the food. During the posttest interview, Apricot said:

> I started a garden. I want to eat stuff grown locally more, more than just stuff that I don't know where it comes from. Like I said, that freaks me out. I can eat from my garden instead of going to the store and getting packaged stuff. The packaged stuff has been everywhere like in trucks and factories and I don't like it.

Similarly, Jalapeño wrote on the feedback questionnaire, “When buying fresh food, if I want to buy in store or go to farmers market. [I think of] how many hands have touched the product before [it’s] going to [the] store.” Jujube had a similar idea about the need to know what the food had been in contact with. During the posttest interview, she said:

> I'd support [a better system] by just starting to make my own food. And probably encourage other people to start making and eating their own food. Because one, it's healthier. You know what you're putting into your food and you know what's all going into your food. And stop getting it from a store where it's already been packaged and you don't know what's been in it, what's touched it, and you know

> that the thing that you're making has only been touched by you or anybody supervised by you.

During the posttest interview, Kiwi added about how systems thinking brought awareness into thinking of local fresh foods rather than processed foods from further away. He was more comfortable to eat fresh local foods, because he knew more about the conditions when it was produced than processed food that came from elsewhere. He said:

> [Thinking of food as a system] puts more light on the local farmers than it does the old factories, I think. [To] have people thinking more about the local farmers and the factory people, you know where your crops are coming from and you have a better idea of what happened to those crops throughout the year than you do big factories. They just had a total recall on meat from [a large supermarket] because their factory was contaminated. So, they had to recall all that. I don't want to eat something that I don't know where it came from. I'm picky about what I eat. So, there's sometimes that I do not eat unless it is at home because I know where the food at home and the drinks at home came from and how they got there versus stuff at the store where I was like, I don't know how that was made or where that came from. I don't know if it's bad or not.

Similarly, Blueberry saw the value of being able to ask the local food producers to learn about the products. During the posttest interview, he said:

> I will know that the local foods will be more fresh. So, I would probably go after the local and go to the farmers' market to get that freshness instead of going to like [a large supermarket] or something and getting the not so fresh food. They look equally fresh, but you know where these [local foods] are coming from. And you can ask the farmer ‘what type of fertilizer or what you did [to the foods]’. So, you would have more knowledge over the food or vegetables.

Second, I described how some students intended to choose foods that had *less negative impact on the environment*. Apricot wrote on the worksheet, “I will think about where things come from and [how they] affect the environment before I buy it.” Similarly, Jujube wrote, “[I’d think about] what food[s] affect the environment and what foods that we should support.” Specifically, Nectarine wrote, “[I’d choose] sustainable, locally sourced food. Local farmers market (fresh food, honey) would be great choices. And [I’d] at least try to be careful not to buy too much packaged foods. [Applying systems thinking,] I can realize that paying for food that has been shipped across a long distance is not smart because it is wasting the precious resources of which only so much exist on our planet and we should not waste them.” Likewise, Jalapeño wrote, “I would think about going to the farmers market: (1) to get fresh cut products and (2) [to] have a more variety of products. I would also think about if they used chemicals of natural to [on] their farms. [Applying systems thinking,] I can think about if it is good for the environment or causes harm or how the product was made/packaged." During the posttest interview, Kiwi, who also wanted to choose local fresh foods over processed foods, addressed the problem of high consumption of packaged food in the landfill. He elaborated:

> I was watching the news. They have one big landfill. But they now had to go across the street and build another. What it is a literal mountain of garbage with dirt thrown on top of it. Because there's been an increase in people buying groceries and packaged factory-made meat and chicken instead of from the local farmers.

Third, I described how some students thought about foods with a concern about the societal issues. Nectarine wrote on a worksheet showing that he realized the importance to address the unfair wage. He wrote, "Labor should be paid for their help." While other students stated that buying local products would *support local farmers and local community*. In addition, students identified that food could be donated to help people in need. Blueberry said during the posttest interview that he could support a sustainable food system "by buying the local products [and] supporting local businesses." Arugula wrote, "[I'd apply systems thinking by] eating from local food markets and helping with donating." Kale wrote, "I will try to buy fresh food that is grown locally." Spinach wrote, "I could share what I learned with other people. [I would] help provide for people in need." During the pretest interview, Apricot saw the importance of knowing where food comes from to support the local farmers. She said:

> I don't think I ever thought about why it was important [to go to the farmers' market]. As a kid I was like, 'ooh, we're going to get corn.' I wasn't excited about it. It was just something to eat. I never thought about where it came from. So now that I know if I go to a farmers' market, I'm getting food from local farmers instead of just being shipped from like five countries over.

Next, I described how students intended to take specific actions that would lead to a more sustainable food system. Nectarine pointed out the importance of a change in the system to reduce food waste at the scale of food business by giving them information and support. During the posttest interview, he explained:

> I think the community should be aware of what's going on and I think we should try to change the system. There's a lot of different ways—social media would be

> one. If someone really feels a passion for changing it, they should just dedicate themselves to trying to change it, to contacting businesses, to contacting people. Give them a packet of information that they [the food businesses] can look through and then, you know, 'Here's my number. If you really feel like you want to try to change and not throw out so much food, I can help you.'

In addition, Nectarine would support the local farmers as well as stop supporting large food businesses to call for a change in reducing food waste. He said:

> Probably buying local food—direct from farmer to help support the farmer for one thing. And because that will go through the feedback loop to large farmers or maybe a bit large businesses. And I can say like, 'I'm not supporting you because you're wasting food, because I don't believe in what you're doing.' Not like, you're terrible. But I think it needs to change.

During the posttest interview, Apricot added that she would change her actions or behaviors if she was aware that it had a negative impact on the environment. She shared:

> If I realized that there's something that needs to be changed, I'll change it. Like if I realize that I'm harming the environment when I'm doing something as a system—something that is part of something bigger. And I'm doing it as a negative impact on the environment. I'll change it because now I realize what I'm doing.

Apricot added that more people should be aware that a certain product had a negative environmental impact. Therefore, not purchasing the product could lead to lowering the production. Educating could also create a change. She said:

> Maybe if we, if I told people about what we are doing to our environment and like 'if you stop buying a certain product that's maybe the making of it is bad for the environment, then they'll stop producing it.' If a lot of people stopped buying it, they won't have a need to produce it anymore or so maybe if you, if I told people about what we're doing to the environment, like educating them like you are. Then people would be more aware, like you've made our class more aware. And we will be able to do something and change it.

Apricot shared about her encounter with a customer who avoided using disposable materials. The experience made her intend to reduce waste and recycle more. She said:

> A girl came into our restaurant the other day and she was really mad because we only had Styrofoam cups because they're not biodegradable and that's also bad for the environment. And then she was like, 'you can keep your straw and your lid.' And since then I've thought about doing something about that, like getting rid of

> the Styrofoam cups even though it's out of my control. So maybe I'll take reusable bags to the grocery store and just recycle more.

During the posttest interview, Jujube discussed that more people including herself should buy fresh food with minimal packaging to increase the demand for healthier foods and to reduce the production of processed and packaged food. She said:

> People should go and encourage more healthy foods to be bought and also eaten because in America, we have a lot of fast food restaurants and a lot of that's just not healthy for us. And so, if we encourage more people to buy healthy foods, that would really help the environment and not much food would have to be processed and packaged. And we can just end up making it ourselves because we're capable and able to do it. If I were to pick fresh foods, and if the store were to see that more people were buying fresh foods, more fresh foods would end up going into the store than packaged foods.

Jujube also discussed about how she currently ate what was already in the fridge before getting new foods in order to reduce food waste. She said:

> I've been watching what I've been eating lately. And I try to eat any leftovers I have instead of going out and getting new food. And it saves like a lot of money. [Before this,] if I felt like eating something, I would go out and get something. But now, I just look [at] what's in the fridge and eat whatever's in the fridge. And then once the fridge gets empty, I go out and get more food to use up all the food that's still good instead of throwing it away and wasting it.

Jujube also discussed about ways she could tell other people about using foods after expiration date to reduce food waste problem. She said:

> A lot of people just end up throwing their food out in a way. I can solve that problem by letting people know that, 'Just because it's been in your fridge for like a week doesn't mean it's necessary bad. It probably just needs to be warmed up and then you can still eat it. It's still edible and you can use your nose to smell if it still smells good. And then, if you don't see any mold growing on it, you can still eat it.' Stuff like that.

Finally, I described how students intended to apply systems thinking in their future projects related to promoting a sustainable food system. Nectarine, who was starting a garden, explained about applying systems thinking in planning a location for his crops with the consideration of functions and external factors. He said:

> Because when I harvest, I want it to be easy to harvest everything and I want watering to be easy and I want it to make sense where I put things. So, like we have a rabbit that lives in our yards. So, I want to put plants around the edge of the garden that is going to keep the rabbit from getting into the lettuce that I'm going to put in the middle. Different things that I've learned from the field trips will help when I plant the garden.

Kiwi, who was working on his family farm, reported that he wanted to use the alternative farming strategy. However, Kiwi did not explicitly elaborate on how systems thinking would be applied in this project. Kiwi merely acknowledged that he learned about natural farming techniques such as rotating crops and using different crops to control pests from one of the field trips. Kiwi wrote on feedback questionnaire, “When farms plant and grow crops, when ranchers move cattle, using natural substances to grow crops instead of always using chemicals. Not overgrazing cattle and horses on the same part of property but moving them around.” During the posttest interview, he expressed his intention to use the natural methods starting on a small part of his family farm.

Jujube, who wanted to be a veterinarian in the future, discussed about her intention to apply systems thinking in her work to reduce the use of synthetic chemicals on the large animals. However, Jujube also did not explicitly elaborate on how systems thinking would be applied in this task. She said:

> In the future, if I’m working with large animals, I can help animals become healthier in a more natural way without using antibiotics. Maybe I can do some research about what foods help animals grow more fat, or grow more muscle, something along those lines.

4.8 Chapter Summary

This chapter discussed the findings to help understand high school students’ systems thinking in the context of sustainable food systems. The findings were presented in four sections: (1) Students’ Background and Previous Experiences; (2) Students’ Demonstration of Systems Thinking; (3) Instructional Design for Systems Thinking; and (4) Applications and Benefits of Systems Thinking. First, students’ background and prior experiences related to food systems and sustainability were identified prior to the sustainable food systems learning experience. All participants represented a wide range of background and experiences in terms of purchasing and cooking food, and knowledge in agriculture, sustainability, and environmental topics. Second, students, who demonstrated systems thinking throughout the learning experience, described a web of connections within a food system and between systems, understood characteristics of a food system, and viewed a food system from multiple perspectives in spatial and temporal dimensions. Third, overall students reported positive experiences toward online lessons and experiential learning activities. Students discussed about the design features that engaged or hindered them in practicing systems thinking and learning about sustainable food systems. Fourth, students discussed about several benefits of systems thinking. Students reported that they could apply systems thinking to better understand complex phenomena and make decisions or take actions to support a more desirable and sustainable food system.

CHAPTER 5: CONCLUSIONS

5.1 Chapter Overview

This chapter is a summary of the conclusions for the study. Four major conclusions of the study were presented in the following topics: (1) attributes of students who demonstrated systems thinking; (2) systems thinking in the context of sustainable food systems; (3) instructional design for systems thinking; and (4) applications and benefits of systems thinking. Implications for practice and policy as well as recommendations for future research are presented at the end of this chapter.

5.2 Purpose of the Study

The purpose of this study was to explore and describe high school students' systems thinking throughout a sustainable food systems learning experience, which was designed for students to practice systems thinking. Further, the researcher sought to explore how the learning experience helped students practice systems thinking and how students intended to use systems thinking beyond the learning experience.

5.3 Research Questions

Three research questions guided this study:

1. In what ways did students demonstrate systems thinking throughout the sustainable food systems learning experience?
2. How did the instructional design of this learning experience help students learn about, engage in, and practice systems thinking?
3. How did students intend to apply systems thinking beyond the learning experience?

5.4 Conclusions of the Study

Four major conclusions for this study were discussed in this section along with how the findings were related to prior research and how they contribute to existing literature. Using qualitative case study approach, this study was conducted on a small number of participants but offered a rich dataset to illuminate important findings. The findings were discussed with the theoretical perspective and conceptual framework that guided the study.

5.4.1 Attributes of Students Who Demonstrated Systems Thinking

Conclusion 1: Students who demonstrated systems thinking had the following attributes: (1) they were motivated; (2) they were open-minded; (3) they were aware of holistic thinking; and (4) they had various levels and types of food systems backgrounds and experiences.

As discussed in *Chapter 4*, four students in this study demonstrated systems thinking and three students did not. There were insufficient data to analyze systems thinking abilities of the other five students. Therefore, this conclusion focused on describing the attributes of seven students. Before the learning experience started, participants' background and prior experiences related to food systems and sustainability were identified. These seven students had exposure to agriculture, food, and environmental studies at different levels. For example, Kiwi and Nectarine had a high exposure to agriculture while Apricot, Blueberry, and Jalapeño had limited exposure to agriculture. All students except Nectarine purchased and cooked food frequently. Apricot, Blueberry, and Raspberry wanted to pursue or already had a job related to cooking. Jujube and Nectarine learned about the environment periodically while Apricot and Jalapeño did not have a frequent opportunity to learn about the environmental topics. There were no patterns that having a strong background and experience in agriculture, food, and environmental studies played a role in students demonstrating systems thinking in the context of sustainable food systems.

This conclusion revealed that systems thinking could not be assessed by the level of content knowledge nor predicted from background and prior experiences in certain topics (i.e., agriculture, food, and environmental studies) because content knowledge could be memorized whereas background and experience could be limited to specific events and areas rather than a bigger and holistic picture. Although a student did not need to have a strong background and experience, some level of background and experience is still relevant to systems thinking. According to Bruner (1966), learning is an active process in which past knowledge helps learners construct new ideas or concepts. As systems thinking is a mode of thinking about seeing a whole system and its interacting parts (Bartlett, 2001; Kasser, 2018; Lee et al., 2017; Ponto & Linder, 2011), students still needed to utilize content knowledge to make connections and demonstrate systems thinking. Therefore, they still needed to have some knowledge in agriculture, food, and environmental studies. This conclusion merely showed that students needed to be taught to think in systems thinking way, apart from being taught about content knowledge, which will be discussed further in *Section 5.4.3*.

I also explored students' knowledge of the term sustainability because sustainability is a concept that emphasizes holistic approach (Purvis et al., 2019), which highly related to systems thinking. Prior to the learning experience, Jalapeño and Nectarine were able to define sustainability closest to the theoretical perspective that informed this study. They both demonstrated systems thinking from the beginning and throughout the learning experience. Additionally, some students had mindsets that aligned with systems thinking, which contributed to the demonstration of systems thinking. First, Apricot stated that it was a common sense that everything must start somewhere and go somewhere. This idea aligned with systems concepts of input, output, stock, and flow (Meadows, 2008; Ponto & Linder, 2011). She also perceived that different parts contributed to a food system being whole. Second, Nectarine believed that all systems are intrinsically connected and it was difficult to isolate a part out. This idea is considered a holistic approach, which looks at an object as a whole and the whole is different from the sum of its parts (Bawden et al., 1984; Bawden, 1991; Meadows, 2008; Valerdi & Rouse, 2010; Verschuren, 2001). The findings showed that students who understood holistic approach could demonstrate systems thinking.

In addition to knowledge, background, and experiences, students who demonstrated systems thinking expressed their thoughts showing that they were open-minded. This aligns with the literature stating that systems thinking considers multiple perspectives in order to better understand the complexity (Ponto & Linder, 2011; Valley et al., 2017). For example, Nectarine, Apricot, and Jujube made connections of food systems in relation to health, environmental, economic, and social aspects (see Chapter 4, subsection 4.5.1.2) and they discussed how they valued other people's opinions (see Chapter 4, subsection 4.5.3.1). In contrast, Blueberry and Kiwi, who did not demonstrate systems thinking, were not as open-minded. Blueberry said he was not concerned about other people's opinions if they argued about something he did not care about. Kiwi also expressed that he was not in favor of changes in his farming and eating routine nor changes in the community around him. According to the literature, open-mindedness was also found to be an ideal attribute for critical thinking, which is another type of higher-order thinking skills (Facione, 1990).

Finally, there was a pattern between students' motivation and their demonstration of systems thinking. Students who were motivated during the learning experience demonstrated systems thinking. For example, Nectarine expressed his motivation to learn by stating that he enjoyed any kind of learning. This was also confirmed by his mother who shared with me that he was interested in and enjoyed learning about the food systems topics. Apricot also consistently expressed a positive attitude toward learning. She stated that "knowledge is power" and she felt that learning about food systems and thinking in a systems thinking way were eye-opening and beneficial. According to the literature, students' motivational beliefs, values, and goals helped them chose to engage in the learning experience that led to achievement (Eccles & Wigfield, 2002). On the other hand, students who were unmotivated during the learning experience did not demonstrate systems thinking. Kiwi stated that the content knowledge taught on the lessons was not new to him. Blueberry only expressed an interest in nutrition aspect of a food system because he would like to pursue a weight training career. He stated that learning about other aspects of food systems was not important to him. This was supported by the literature that both students felt unmotivated to learn due to the feeling that the experience was irrelevant (Beane, 1995; Fusco, 2001; Johnson, 2002; Kim & Frick, 2011).

5.4.2 Systems Thinking in the Context of Sustainable Food Systems

Conclusion 2: Students demonstrated a combination of systems thinking abilities in the context of sustainable food systems by extensively explaining about a food system's various connections, complexity, wholeness, changeability, cyclic nature, and feedback loops in temporal and spatial dimensions using multiple perspectives.

A sustainable food system is a complex system that consists of several processes and components that interact with social, cultural, political, economic, health, and environmental conditions at multiple scales (Grubinger et al., 2010). Using this context, high school students in this study showed systems thinking abilities in the context of sustainable food systems by: (1) describing a food system in terms of its complexity, wholeness, and a web of connections within a food system as well as between a food system and other systems such as health, environmental, economic, and social systems; (2) showing their understanding of the nature, behaviors, or characteristics of a food system in terms of changeability, cyclic nature, and feedback loops; and

(3) using multiple perspectives and spatial and temporal dimensions in viewing events or processes in a food system.

The findings suggested that systems thinking is a combination of abilities in three domains regarding describing a system, understanding a system, and viewing a system, rather than just one domain or hierarchically. For describing a system as the first domain, a systems thinker sees a system as a whole rather than focusing on a single part (Bartlett, 2001) and sees various interactions of processes and components within the system and with other systems (Ben-Zvi Assaraf & Orion, 2010b; Meilinda et al., 2018; Valerdi & Rouse, 2010). Specifically, systems thinkers in this study could explain about growing, processing, and consuming in terms of inputs, influences, and outputs (Chase & Grubinger, 2014) with the three pillars of sustainability (Purvis et al., 2019). In contrast, other students either memorized complex connections without being able to come up with a complex connection on their own, made simple connections between a few parts of a system, or made linear connections in a step-by-step manner, which is systematic thinking (Bartlett, 2001; Kasser, 2018).

For understanding a system as the second domain, a systems thinker recognizes the nature, behaviors, and characteristics of a system (Meadows, 2008; Scherer et al., 2017). Specifically, systems thinkers in this study recognized that a food system is constantly changing because a variable could change over time (Ateskan & Lane, 2018; Moore et al., 2010; Ponto & Linder, 2011), for instance changes during the industrialization of agriculture. It is important that a systems thinker discusses the change with respect to the whole system rather than merely a change of a single event in a system. Systems thinkers in this study also understood a nonlinear state or a cyclic nature of a system (Ben-Zvi Assaraf & Orion, 2010b; Meadows, 2008; Valerdi & Rouse, 2010), for instance surplus food and feces returned nutrients back into food production. In contrast, other students viewed that after consumption, the food system ended and another system started. This is rather a concept of reductionism, which breaks a system into separate parts (Valerdi & Rouse, 2010; Verschuren, 2001). Additionally, systems thinkers in this study recognized a process of feedback, which the output of a system is fed back around to regulate the system (Meadow, 2008; Meilinda et al., 2018; Ponto & Linder, 2011) and that an individual should learn from the consequences of their own actions rather than assume that others are at fault (Stroh, 2015). They understood that some parts of a system communicated and were dependent on each other (Clancy, 2013), for instance consumer demand could increase or decrease the production of a food item. Other students did not discuss about anything related to feedback loops.

For viewing a system as the third domain, a systems thinker values multiple perspectives (Valley et al., 2017) and thinks spatially and temporally (Lee et al., 2017; Meilinda et al., 2018). Specifically, systems thinkers in this study used different disciplines and other people's viewpoints in viewing the complexity of a food system. When discussing about a food system, systems thinkers talked about various aspects including health and nutrition, environmental impact, community well-being, economic factors, and politics. In terms of space, systems thinkers in this study made connections with spatial dimension, for instance change of land use and a food system in different countries. In terms of time, systems thinker in this study discussed about behaviors that occurred over time or the time period of interest (Meadows, 2008; Ponto & Linder, 2011), for instance impact of the Dust Bowl and nutrient loss from planting year after year.

The findings were synthesized to create a model for systems thinking in the context of sustainable food systems (see Figure 5.1). The model shows a combination of three systems thinking domains: (1) describing a system; (2) understanding nature and behaviors of a system; and (3) viewing a system. The first domain focuses on describing a food system by expressing a web of connections or relationships within a food system and between a food system and other systems. To show the abilities of systems thinking, an individual should be able to discuss about the wholeness of a food system rather than separate parts as well as the complexity from small entities that make up a food system. The individual should also discuss about connections of a food system with other systems as well as how they reflect and respond to each other (i.e., two-way consequences).

The second domain focuses on understanding nature, behaviors, or characteristics of a food system. The individual should be able to recognize the ability of a food system that could change because of the variables involved in the system, a cyclic nature or how a single or series of events could return to the starting point, and the feedback loops or how the output of a food system could be fed back around to regulate the system.

The third domain focuses on what kinds of lens to use in viewing a food system. The individual should be able to use multiple perspectives to look at a food system. These perspectives include perspectives from different disciplines, personal standpoints (e.g., position of power, social status), and other people's viewpoints and opinions. Additionally, the individual should take spatial dimension into consideration when viewing a system by recognizing the factor of a continuous area (i.e., space) and a particular position (i.e., place). Lastly, the individual should take temporal dimension into consideration when looking at a system by recognizing the factor of time horizon or length of time as well as what had happened in the past (i.e., retrospection) and what would happen in the future (i.e., prediction).

Each student who demonstrated systems thinking in this study was different from each other in terms of the details of the categories under each domain that they expressed. Students who were exemplary demonstrated all subcategories presented in Figure 5.1, while the other demonstrated only some subcategories. Nonetheless, all students who demonstrated systems thinking expressed their systems thinking abilities from all three domains.

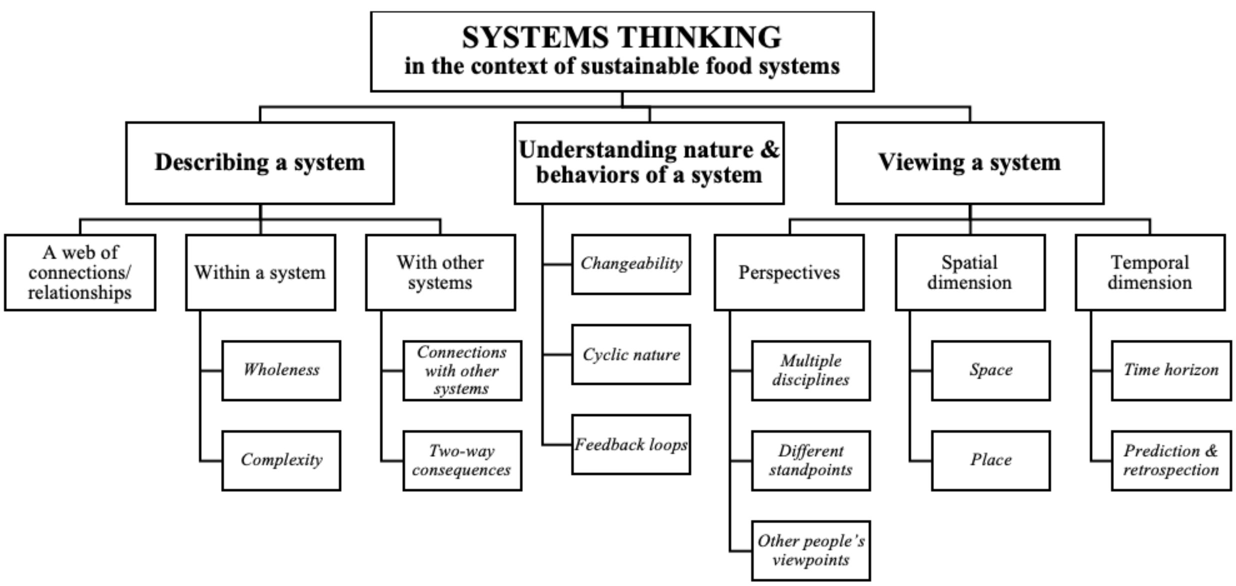

Figure 5.1: Systems Thinking Model in the Context of Sustainable Food Systems

The findings of this study revealed that systems thinking is not a linear or hierarchical process. Rather, it is based on a nonlinear and holistic process. The findings contradicted the System Thinking Hierarchical model (Ben-Zvi Assaraf & Orion, 2010b). Specifically, some students (i.e., Kiwi and Raspberry) were able to identify the cyclic nature of a food system, which is the fifth level of the model, while they struggled to demonstrate other abilities in the lower level of the hierarchical model (i.e., identifying dynamic relationships within the system and organizing the system's components, processes, and their interactions, within a framework of relationships). Some students (i.e., Apricot and Jujube) discussed during the pre-test interview about the feedback loops (i.e., systems' mechanisms on the sixth level of the model), but not until the post-test interview that they recognized the cyclic nature of a food system (i.e., the fifth level of the model).

The findings of this study also revealed that systems thinking is complex and involves several systems concepts. Therefore, qualitative analysis is more appropriate than the quantitative analysis to capture how an individual demonstrates systems thinking because the quantitative data collected by this study was reductionistic and not supported by the qualitative evidence of how students demonstrated systems thinking. Specifically, on the self-report quantitative results of students' systems thinking scale (see Table A, Appendix H), students who had a high score did not demonstrate systems thinking and vice versa. Moreover, the findings revealed that using multiple data sources (e.g., interviews, Applesauce assignment, reflections) to capture students' systems thinking was appropriate in analyzing different domains of systems thinking abilities, which were complex and detailed.

5.4.3 Systems Thinking Instructional Design

Conclusion 3: Students who thought in a systems thinking way benefited from the instructional design features in practicing systems thinking in the context of sustainable food systems and they recognized that systems thinking was challenging and time-consuming, whereas students who did not think in a systems thinking way struggled to come up with their own answers and only benefited from learning about content knowledge and some systems concepts instead of how to think in a systems thinking way.

The sustainable food systems learning experience was the common experience among the participants of this study. Applesauce assignments, online lessons with worksheets, and the experiential learning activities served as instructional components that aimed to increase students' knowledge and understanding about sustainable food systems and provide the opportunities for students to practice systems thinking. The findings suggested that the learning experience gave the opportunity for students, who already knew how to think in a systems thinking way, to practice systems thinking in the context of sustainable food systems. However, students, who did not think in a systems thinking way, learned about systems concepts and the content knowledge about sustainable food systems but did not develop systems thinking.

Students, who were a systems thinker, engaged in the learning experience and discussed about how it challenged them to think, make connections, and see a new perspective. Students met the expectation of the learning objectives. They reported that the assignments became easier after the learning experience. Although, some students enjoyed being asked to think and recognized the value of a lot of thinking, they shared that they were getting exhausted of thinking, not always feeling motivated to think outside the box, or getting tired of writing explanations.

Another challenge that students reported was not being provided sufficient time for their assignments. Students needed more time to think, interpret the questions, and come up with answers, which made the learning more difficult than finding and memorizing the answers. This required students to think in a broader scale, which requires a length of time for students to practice in order to reach an adequate level of expertise (Spelt, Biemans, Tobi, Luning, & Mulder, 2009).

Students, who did not demonstrate systems thinking, were confused about the expectations of the learning experience. They reported that they learned and understood more about the content knowledge of sustainable food systems topic. However, they discussed about the hindering factors in learning about systems thinking. These factors included insufficient guidance and examples, difficulty of finding the information to complete the assignments, and difficulty in coming up with answers from their own thinking. This supported the literature stating that schools in the United States focus on rote memorization and do not typically teach higher-order thinking to students (Ichsan et al., 2019; Mayer, 2002; NRC, 1988; Smith & Szymanski, 2013; Valerdi & Rouse, 2010), which resulted in students not being used to doing a lot of thinking.

The findings also suggested that self-directed lessons were not effective for students who did not think in a systems thinking way. As suggested in the literature (i.e., Hiller Connell et al., 2012; Valerdi & Rouse, 2010; Verschuren, 2001), thinking in systems thinking way is not intuitive and human evolution has favored a reductionist reaction rather than a holistic reaction. Therefore, thinking in a systems thinking way must be taught explicitly to students, who associate learning with memorizing facts, on how to make a web of connections using existing content knowledge, apply facts to understand the nature and behaviors of a system, and view a system in other dimensions.

In addition, students who did not demonstrate systems thinking reported that they preferred reading text to the video lectures. Not seeing texts especially made it more difficult for the students to find answers, follow the lectures, and grasp the messages. This aligned with Jensen's (2011) study, which found that students preferred in-class lectures to online lectures because more structured environment is easier to maintain attention. Bennett and Maniar (2012) also discussed that there were conflicting findings whether video lectures offered benefits for course satisfaction and confidence, made no significant difference, or had an adverse effect on attendance. They discussed that the lecturers' enthusiasm became less interesting on the small screen (Bennett & Maniar, 2012).

In terms of improvement for the future instructional design, the findings suggested that providing a structure was helpful. However, it could limit how students expressed their ideas from systems thinking. The systems thinking model should be used in designing the future curriculum to offer the opportunities to teach the three domains of systems thinking, which are describing a system, understanding its nature, and viewing a system (see Figure 5.1). Additionally, students reported to have trouble with demonstrating systems thinking by writing because it tended to be lengthy and time-consuming. Therefore, verbal expression, drawing diagrams, simulation, and project-based activities could be considered in order to reduce writing assignments. However, writing assignments should not be replaced because writing is a more effective tool than oral description in supporting problem-solving tasks and metacognitive behaviors (Pugalee, 2004).

The instructional component that all the participants in this study found valuable was the experiential learning activities. Students discussed about enjoying the activities, experiencing first-hand what was taught in class, knowing more about their local food system, and gaining techniques that they could apply in their farms or gardens, especially from interacting with guest speakers and visiting the farms. This aligns with the existing literature (e.g., Goralnik et al., 2018; Jordan et al., 2014; Knobloch, 2003) that the active learning through experiential learning activities made learning personal and useful as well as helped students make connections and apply knowledge beyond their classrooms.

5.4.4 Applications and Benefits of Systems Thinking

Conclusion 4: Although not all students could demonstrate systems thinking, most of them recognized the benefits of systems thinking in helping them better understand complex phenomena when solving problems and performing tasks. Students, who demonstrated systems thinking, elaborated the applications of systems thinking in supporting a desirable and sustainable food system through food choices, food-related decisions, and future projects.

In this study, applications of systems thinking were explored based on two main goals of systems thinking: (1) to help an individual better understand complex phenomena (Ponto & Linder, 2011); and (2) to support an individual in making decisions to change a system to be more desirable and sustainable (Arnold & Wade, 2015; Bawden, 1991; Ponto & Linder, 2011). The findings revealed that the study participants, although could not demonstrate systems thinking, recognized the benefits of systems thinking, which helped shed light into advocating for systems thinking instructions. As the literature identified systems thinking as a way of thinking to help an individual identify root causes of complex problems and see new opportunities, ideas, concepts, techniques, and tools to solve them (Boardman & Sauser, 2008; Meadows, 2008), students identified that systems thinking could help them see a bigger picture, understand how something could affect or be affected by other things, enhance working processes to become easier and quicker, understand complex systems, and understand other perspectives.

Students, who demonstrated systems thinking, elaborated the importance of systems thinking further. For example, Nectarine addressed that systems thinking could help find effective ways to maximize the use of a resource for various processes in order to conserve resources. Apricot recognized that consumers have been influenced by perspectives from the media and latest discoveries, which implied self-awareness about influences on her decisions. In addition, she stated that systems thinking could help people understand something thoroughly, which would lead to advancements in research and environmental improvements.

In terms of application, educators believe that systems thinking could support students in making decisions to change a system to be more desirable and sustainable (Arnold & Wade, 2015; Bawden, 1991; Ponto & Linder, 2011). As high school students will soon make their own decisions on what to eat and what to purchase, students were asked to discuss about their food-related decisions. The findings suggested that most study participants intended to purchase locally grown and raised fresh food from a farm that used natural methods and used a minimal packaging. Only students who demonstrated systems thinking could elaboratively discussed about what actions could be taken that would lead to a more sustainable food system, while other students limited their responses to food choices.

Some students intended to find natural methods in caring for livestock and use natural products in growing crops as part of their future projects. Some students intended to reduce food waste by eating leftovers, donating, and communicating with businesses about reducing food waste. This aligns with the literature stating that systems thinking helps people see the interconnections within food systems far in advance before and after the point of consumption (Widener & Karides, 2014). All systems thinkers in this study recognized that producers and retailers provided food that met consumers' demand. Therefore, consumers should show their demand by choosing only healthful products and products that had less environmental impact. The support for more sustainable products would send a message to the producers and the retailers to supply the desirable food, which ultimately would support a sustainable food system. This aligns with the literature stating that a systems thinker takes responsibility to begin changing themselves and create what they want rather than depending on others to change (Stroh, 2015).

5.5 Implications for Practice

This section provides implications for curriculum developers and educators regarding systems thinking instructions in the context of sustainable food systems based on the findings from the case study. The implications highlighted two levels of the instructions: (1) the implications for teaching students who do not think in a systems thinking way; and (2) the implications for teaching students who already think in a systems thinking way to practice systems thinking in the context of sustainable food systems.

For teaching students who do not think in a systems thinking way, the findings support the existing literature (i.e., Mayer, 2002; NRC, 1988; Smith & Szymanski, 2013; Valerdi & Rouse, 2010) stating that the emphasis of instruction has been put on rote memorization or fact recall, while human evolution has favored a reductionist reaction (Valerdi & Rouse, 2010; Verschuren, 2001). This might explain why some students were confused about the learning objectives of the learning experience. Therefore, it is important for educators to explain to students prior to implementing the curriculum that the expectations would likely be different from what students are used to. Students should be told that they are expected to come up with their own answers instead of merely memorizing the given information. They are expected to understand systems as being interrelated, complex, and whole rather than separated and linear (Bartlett, 2001; Kasser, 2018; Valley et al., 2017). Students would better engage, learn, and transfer the learning when they are aware of a broader set of potential learning outcomes (Coker & Porter, 2015).

Systems thinking instructions should put more emphasis on teaching systems concepts than on the content knowledge. Based on the findings, several students were worried about the exact details or technical terms of components and processes in the food system that they were not familiar with, which is rather a goal for an instruction that puts an emphasis on rote memorization (Mayer, 2002; NRC, 1988; Smith & Szymanski, 2013; Valerdi & Rouse, 2010). It is important to clarify with students that they should not be stressed over getting the terms correctly so much that they forget to try to understand the web of connections, the nature and behaviors of the system, and different ways they should view a system.

In terms of instructional design before starting the first lesson, I strongly recommend a brain warm-up or scaffolding exercises to prepare students mentally for systems thinking. For instance, a word association activity (Ben-Zvi Assaraf et al., 2013; Ben-Zvi Assaraf & Orion, 2005a) could be implemented by giving students a topic and ask them to associate the topic with as many words as possible. A picture description activity (Witjes et al., 2006) could also be implemented by having students look at pictures or drawings and provide explanations of relationships they see along with several different events of what could have happened, is happening, or will happen.

The findings revealed that self-directed lessons were not sufficient to get students to understand these learning objectives. Students needed more structure and guidance to complete the reflection questions that were not used to doing. This is because students tend to be familiar with a stronger structure in most classrooms rather than performing higher-order thinking tasks (Ichsan et al., 2019; NRC, 1988; Smith & Szymanski, 2013). An instructor should constantly remind students that they need to come up with their answers and put a lot of thought into responding to the assignments. The instructor should be available to assist students or provide immediate feedback when students fail to do so or when students use reductionistic approach. In addition, self-directed lessons could not direct students with other specific mindsets into systems thinking. The instructor needs to observe and provide guidance. Specifically, students who demonstrated systematic thinking, which is thinking in step-by-step manner, could have been facilitated to practice making a web of connections.

There is no single pathway to teach systems thinking to a student because systems thinking is a combination of a set of abilities. However, it is a crucial starting point for a student to understand that a system is “a set of elements or parts that is coherently organized and inter interconnected in a pattern or structure that produces a characteristic set of behaviors, often classified as its function or purpose” (Meadows, 2008, p. 188). Then, the student could practice thinking about how everything connects to everything else by either affecting on, being affected by, or both. Educators could highlight specific systems concepts from a certain content knowledge, then proceed to have students apply the systems concepts to other situations or contexts. For example, when learning about nitrogen cycle, educators could point out the cyclic nature of a system that also applies to milk, banana peel, and feces. When discussing about nature or behaviors of a system, simulations could help a student visualize the systems concepts easier. The following paragraphs discussed further about teaching systems thinking based on the three domains from the findings.

For teaching students who could think in a systems thinking way, the educator should keep in mind that students most likely do not know what systems thinking is. Moreover, systems thinking is not typically taught in schools (Ichsan et al., 2019; NRC, 1988; Smith & Szymanski, 2013), therefore, students will benefit from practicing the skills. Based on what students reported, I propose a strong recommendation to allow sufficient time for students to process their thinking in a systems thinking way. As systems thinking involved several concepts, the findings suggested that it is helpful to provide a structure that helps students organize their thoughts. The model developed by this study (see Figure 5.1) based on the findings and the literature (e.g., Ben-Zvi Assaraf & Orion, 2010b; Meadows, 2008; Meilinda et al., 2018; Ponto & Linder, 2011; Valerdi & Rouse, 2010) could serve as a structure for teaching all three domains of systems thinking.

According to Pugalee (2004), writing is a more effective tool than oral assignment in supporting metacognition because it involves deliberate analytical structure in making the text fully understandable while connecting current and new concepts. However, the findings suggested that students were not always motivated to complete the written assignments.

Therefore, I recommend a class discussion to help generate ideas and give students the opportunity to hear from multiple perspectives before implementing writing assignments. Drawing a diagram (Cox et al., 2017) could also illustrate how students make connections, but detailed instruction or a concrete example need to be provided in order to prevent students from simplifying their diagrams. When possible, reflective essay (Galt et al., 2013; Lattuca et al., 2004) should be assigned for students to organize their thoughts and practice systems thinking.

In terms of using sustainable food systems as a context for practicing systems thinking, the findings provided a guideline for assessing systems thinking. Students should demonstrate a collection of systems thinking abilities in three domains. First, students should be taught to discuss about a complex food system by making various connections of what, who, how, and why regarding the different processes (i.e., food production, processing, distribution, consumption, and disposal of food and food-related items; Chase & Grubinger, 2014; Gillespie & Gillespie, 2000) within a food system in order to see a bigger picture and eventually a whole rather than separate parts. Then, students should see an even bigger picture of how a food system connects with other systems such as health, environmental, economic, political, and social systems (Hilimire, 2016; Hilimire et al., 2014; Parr et al., 2007).

Second, students should be taught to extensively explain nature, behaviors, and characteristics of a food system, especially regarding changeability (i.e., industrialization of agriculture, crop rotations, technological improvement, and science discovery), cyclic nature (i.e., composting surplus and leftover food, wastewater treatment for feces, and recycling food packaging), and feedback loops (i.e., demand and supply, consumer support, and natural resources utilization). The literature also suggested other systems concepts such as delay, boundary, structure, stock and flow, event and pattern, mental model, and leverage point (Ponto & Linder, 2011) that should be highlighted with a certain topic.

Third, students should be taught to consider other perspectives in viewing a food system by looking at the food system from different standpoints such as from a perspective of a producer, shopkeeper, consumer, and garbage collector, listening to other people's opinions, and using multiple disciplines (Spelt et al., 2009) because a food system has an impact more than just our health but also the environment, economy, and society (Purvis et al., 2019). Students should understand the relation of a food system with spatial dimension (e.g., where each process takes place and how much area is needed) and temporal dimension in the timeline and duration (i.e., pollution from the Dust Bowl, the delay effect of climate change, and how long it takes for each process).

Fourth, educators need to explicitly teach students about the benefits and importance of learning systems thinking in the context of sustainable food systems. Students need to recognize skills and techniques that they could directly apply to everyday life and future careers in order to be motivated to learn. Two main advantages of thinking in a systems thinking way are the ability to understand and solve complex food systems related issues and the ability to support a desirable and sustainable food system by reducing long-term environmental degradation; negative impacts on health and safety of farm workers and consumers; income gap; and food insecurity as a whole (Bawden, 1991; Page, 2013; Valley et al., 2017). Students could contribute to environmental sustainability with pro-environmental behaviors (Mesmer-Magnus et al., 2012), such as supporting local fresh food, not buying food with a lot of packaging, and using natural methods for long-term soil health.

5.6 Implications for Policy

This section provides implications for educational policy based on the findings from the case study. The first implication for policy is the need to support teaching about sustainable food systems topic to high school students. The U.S. ranked 21st out of 34 countries in the 2017 edition of the Food Sustainability Index (FSI) due to several issues including food waste, unsustainable farming practices, and rising obesity (Koehring, 2017). There is a rising demand for the workforce to focus on solving these issues. However, more people become disconnected from the food systems and lack of the knowledge about them (Ebrahim, 2016; Harmon & Maretzki, 2006; USFRA, 2011; Widener & Karides, 2014). As food, agriculture, and environmental studies are not part of the compulsory subjects taught in schools in several states including the state of Indiana (Indiana Department of Education, 2018, 2019), it is important to make the sustainable food systems a mandatory topic in high schools. The findings revealed that not all students, who were also consumers and producers, realized the consequences of their actions that had contributed to an unsustainable food system, which supported the existing literature (e.g., Ebrahim, 2016; Harmon & Maretzki, 2006; Mercier, 2015; NRC, 1988; Trexler et al., 2000). After participating in the sustainable food systems learning experience, students became aware of several complex societal problems and acknowledged how they could be part of the solutions. However, only students who understood about sustainable food systems demonstrated how they intended to take an action in solving food-related complex issues. Teaching sustainable food systems topic would equip those entering the workforce to solve those critical complex problems in the society.

The second implication for policy is promoting the strategy to incorporate systems thinking in teaching agriculture and food-related content. As the current education systems tend to only emphasize reductionistic thinking, systems thinking becomes underdeveloped. It is important to embrace both holistic and reductionistic approaches in the instruction. The findings showed that some students only viewed the importance of food and agriculture to be related to one or a few disciplines. Some students had a limited understanding to a single part of the food system. As the traditional agricultural and food-related curricula focus on linear and narrow production problems (Valley et al., 2017; Williams & Dollisso, 1998), using systems thinking would help investigate and solve real-world complex problems in a broader range than reductionist, discipline-based approaches (Bawden et al., 1984). Systems thinking provides various opportunities for students to relate the content knowledge to everyday life and future careers. Using systems thinking, students could learn to make decisions regarding food and agriculture long before and after the point of consumption that would lead to the desirable and sustainable future instead of a decision that only yields a short-term effect (Arnold & Wade, 2015; Bawden, 1991; Ponto & Linder, 2011; Widener & Karides, 2014).

The third implication for policy is the importance of preparing teachers to be ready to teach systems thinking as a higher-order thinking skill. Currently, teachers in the United States do not typically instruct students to learn higher-order thinking (Ichsan et al., 2019; NRC, 1988; Smith & Szymanski, 2013). Instead, instruction focuses on the components that make up the system rather than the integrated processes that build the system (Ben-Zvi Assaraf et al., 2013). Moving forward, the direction of curricula should be more complex and encourage more thinking, as the findings revealed that students struggled with understanding complexity and coming up with their own answers. Teachers should be trained to teach students to make and understand connections between different parts of a system to better prepare the future generations in addressing critical 21st century issues. The focus from rote memorization and fact recall should be shifted to include teaching students to work on complex problems (Mayer, 2002; NRC, 1988; Smith & Szymanski, 2013; Valerdi & Rouse, 2010).

The fourth implication for policy is changing the way academic achievement is assessed. The findings implied that increasing test scores for memorization and recall skills has been the primary teaching and learning goal and dictated the way a class is structured. This supported the literature that a majority of the standardized testing used to assess academic achievement nowadays has been measuring memorization and recall skills rather than higher-order thinking skills (Krentler, Hampton, & Martin, 1994; Morgan, 2016). It is crucial for policy makers to put an emphasis on evaluating how well students implement systems thinking and other holistic approaches in applying what they learn in order to prepare students to deal with complexity and practical domains outside of their specialization and meet challenges of the fast-changing world (Valley et al., 2017; Wang & Wang, 2011). As the findings suggested, an interdisciplinary topic such as systems thinking in the context of sustainable food systems could help structure a new way to access academic achievement via students' higher-order thinking skills, which include the abilities to integrate multiple disciplines and perspectives beyond memorization and fact recall skills (Hilimire, 2016).

The fifth implication for policy is supporting an experiential learning approach in addition to classroom instruction. Experiential learning activities provide opportunities for students to be exposed to local context to learn about location-specific challenges and specificity of solutions (Francis et al., 2011). Moreover, experiential learning activities offer significant educational rewards including deep learning, practical competence, civic engagement, and professional networks (Coker & Porter, 2015). The findings showed that all students in the case study enjoyed interacting with guest speakers and going on the field trips. The enjoyment would motivate students to engage in learning and lead to achievement in their class (Eccles & Wigfield, 2002). The findings also supported that experiential learning activities helped students make connections to what they learned in the classroom and apply what they learned in projects beyond their classrooms (Knobloch, 2003). With the support at the policy level, all high school students should have the opportunity to learn through experiential learning activities without the limitation of schedule conflict or financial support (Kisiel, 2005).

5.7 Recommendations for Future Research

There are very few studies about systems thinking, especially in the United States. No other studies were found to have explored and described systems thinking among high school students in the context of sustainable food systems. Therefore, more research should be conducted in this area. The recommendations for future research based on the lessons from this study are presented in three areas: (1) research methods and data sources; (2) contexts and participants; and (3) instruction and interventions.

In terms of research methods and data sources, this study showed that a qualitative analysis was more practical than quantitative analysis in exploring and describing the characteristics, applications, and instructional design of systems thinking due to the complexity and variety of concepts. I strongly recommend that the future studies always include the qualitative components. In addition, this study developed the analytical framework (see Figure 3.1) for data analysis. I suggest that the future research use this framework during the research design process to ensure that sufficient data for the three domains of systems thinking are collected.

This study primarily focused on describing participants who demonstrated systems thinking. Future studies could focus on a cross-case analysis between students who demonstrate systems thinking and students who do not. The cases could explore students' mindset and background to find the potential influences or contributions of systems thinking. For example, students could be exposed to different learning environment and have a specific way of viewing the food systems, especially Bawden (1991) discussed about how instruction regarding agriculture has been reductionistic. Both groups of participants could be a qualitative assessment for organizing their thoughts and to determine their systems thinking abilities early on.

Collecting data from different types of instructional materials is highly recommended to ensure that the research is inclusive and holistic. Different materials helped provide the details of students' systems thinking abilities more thoroughly. This study found that the interviews captured students' thought processes with sufficient details, while the assignments could have allowed more opportunity for students to express themselves. The future studies could consider utilizing other methods to collect verbal responses from students (e.g., class discussion, oral presentation, and storytelling) as well as collecting reflective essays as suggested by the literature.

In terms of contexts and participants, the context of this case study was limited to the suburban area in the central region of Indiana with limited numbers of students in one public school classroom and one homeschool. Future studies should be conducted in the urban or rural setting in different regions with more public, private, and homeschools. If the future studies focus on describing characteristics of systems thinking, participants should volunteer to be in the study to ensure that they put a lot of effort in complete the assignments.

Though not a salient finding in this study, the findings could be implied that there were variation of how students from different background demonstrated and did not demonstrate systems thinking. I recommend the future studies explore the systems thinking abilities among participants who are FFA members, homeschool students, small farmers, and large farmers. The studies about systems thinking in the context of sustainable food systems on different groups of students could show a variety of perspectives in their thinking. In terms of culture, Western culture tends to have analytic perception focusing on an object independently of its context while Eastern culture tends to have holistic perception focusing on relationships between the object and the context (Nisbett & Miyamoto, 2005). Future studies could explore whether there is a correlation based on the cultural background. In addition, future studies could also explore attributes and prerequisites skills of the learners. These types of study would provide insights of how to promote, support, or instruct systems thinking to a broader audience.

In terms of instruction and interventions, the findings of this study revealed that teaching different parts of a system and then assuming that students could make connections of a whole system without being explicitly taught was not effective. The findings also indicated that self-directed strategy was not effective in helping students develop systems thinking. Some students who had a systematic thinking mindset or memorized relationships in a system could benefit from guidance and immediate feedback from an instructor. Future studies could explore further to provide evidence whether systematic thinking and this type of memorization could develop into systems thinking and explore the instructional strategies to teach systems thinking to students with specific mindsets. In addition, the findings showed that some students in this study had a difficulty understanding the highly complex content knowledge of sustainable food systems context. Therefore, the future studies could consider offering an entry level of a simpler context or simpler system while also giving more attention in helping those students develop systems thinking.

This study was conducted in a limited time frame of six weeks. The assignments were limited to being completed during class periods without an extra time outside of class (i.e., homework). The findings revealed that students needed a much longer period of time to develop and demonstrate systems thinking. This study also did not have sufficient time to assign the presentation for participants to present how they would apply systems thinking. The presentation could serve as another data source to explore and describe how the experiential learning activities help foster systems thinking. Future studies could consider a period of a semester, a school year, or longer to allow sufficient time for students to reach an adequate level of expertise (Spelt et al., 2009). In addition, the longer time frame would allow longer period for prolonged engagement as well as more researchers for multiple perspectives in analyzing the data. Ultimately, a longer study period might lead to the findings about the development of systems thinking.

Lastly, I was aware that there might be some limitations from me serving as both the curriculum developer and research for this study. Although, I monitored my biases, preconceived assumptions could still exist. Therefore, I recommended that future studies could be done by an external personnel who did not take part in developing and designing the curriculum to address these potential limitations.

5.8 Summary of the Study

This study qualitatively explored and described high school students' systems thinking in the context of sustainable food systems. The findings contributed to the knowledge base regarding the characteristics of systems thinking in this context, the recommendations for teaching systems thinking in addition to the typically reductionist instruction, and the urgent need to prepare the future generations to be able to solve real-world complex societal problems and be responsible for their own actions that could dictate the sustainability of the food system and other systems. The four conclusions for this study were: (1) the attributes of students demonstrated systems thinking included being motivated, being open-minded, and understanding holistic approach despite having limited food systems background and experience; (2) systems thinking is a combination of nonlinear and nonhierarchical abilities, which students could demonstrate by extensively explaining about a food system's various connections, complexity, wholeness, changeability, cyclic nature, and feedback loops in temporal and spatial dimensions using multiple perspectives; (3) systems thinkers used the instructional design to practice systems thinking in the context of sustainable food systems and they recognized that systems thinking was challenging and time-consuming, whereas students who were not systems thinkers struggled to come up with their own answers and only benefited from learning about content knowledge and some systems concepts instead of how to think in a systems thinking way. Therefore, systems thinking needs to be explicitly taught about the systems concepts and the strategies of utilizing the content knowledge in a systems thinking way; and (4) most students recognized the benefits of systems thinking in helping them better understand complex phenomena when solving problems and performing tasks. Systems thinkers elaborated the applications of systems thinking in supporting a desirable and sustainable food system through food choices, food-related decisions, and future projects.

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APPENDIX A. IRB DOCUMENT

PURDUE UNIVERSITY

HUMAN RESEARCH PROTECTION PROGRAM
INSTITUTIONAL REVIEW BOARDS

To:	NEIL KNOBLOCH LILY
From:	JEANNIE DICLEMENTI, Chair Social Science IRB
Date:	02/14/2019
Committee Action:	**Expedited Approval - Category**(7)
IRB Approval Date	02/14/2019
IRB Protocol #	1812021476
Study Title	High School Students' Systems Thinking Skills in the Context of Sustainable Food Systems
Expiration Date	02/12/2022
Subjects Approved:	20

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. FORMS

Purdue IRB Protocol #: 1812021476 - Expires: 12-FEB-2022

PARENTAL CONSENT FORM

High School Students' Systems Thinking Skills in the Context of Sustainable Food Systems

Principal Investigator: Neil Knobloch, Ph.D., Professor

Department of Agricultural Sciences Education and Communication

Purdue University

Key Information

Please take time to review this information carefully. This is a research study that aims to collect data from a 15-session learning experience during February to April over 6 weeks. Students will use online materials for 10 sessions and meet with three guest speakers for 3 sessions during the class period. The other 2 sessions, students will go on two field trips. The schedule depends on your child's classroom teacher. The goal of this project is to promote systems thinking among high school students and to improve the instruction of systems thinking in the food-related context. Systems thinking is important for students in solving complex problems and become a responsible citizen. Your child's participation in this study is voluntary which means that you may choose not to have your child participate at any time without penalty or loss of benefits to which you are otherwise entitled. You may ask questions to the researchers about the study whenever you would like. If you decide to have your child take part in the study, you will be asked to sign this form, be sure you understand what your child will do and any possible risks or benefits. Additional explanations may be more detailed in the sections below.

What is the purpose of this study?

This study is part of the project that provides a sustainable food systems learning experience taking place in 15 sessions of the food science class. The purpose of this study is to explore and describe high school students' systems thinking skills before and throughout the sustainable food systems learning experience, which is designed for students to practice system thinking skills. Further, the researcher seeks to explore how the learning experience will help students practice systems thinking and how students intend to use systems thinking beyond the learning experience. Your child is being asked to participate in this study because your child is a participant in the learning experience. We are inviting all 15 students in this class and the teacher to participate in the study.

What will my child do if choose to be in this study?

When you agree to your child participating in this study, you allow the researcher to analyze their questionnaires and assignment responses in the research. Your child will not do anything different from other classmates unless chosen for the interviews. You as the parent have the right to review the research procedures and survey questions before consenting.

Students in this study will:

1. Participate in a 15-session learning experience during February to April during class period.
2. Complete two survey questionnaires (10-minute and 20-minute) before and after.
3. During the learning experience, engage in all assignments.
4. Only selected students will participate in voice-recorded interviews at the school once in February and once in April during the study period for 30-45 minutes each time.

Data that will be collected in this study included: a background survey questionnaire and a feedback questionnaire, assignments, interviews, researchers' field notes, and teacher's feedbacks and comments.

How long will my child be in the study?

15 class sessions in February and April. The total amount of time to complete two questionnaires and two interviews will be 90 minutes.

IRB No.________________ Page 1

High School Students' Systems Thinking Skills in the Context of Sustainable Food Systems

Principal Investigator: Neil Knobloch, Ph.D., Professor
Agricultural Sciences Education and Communication, Purdue University

ASSENT FORM

We are doing a research study about systems thinking skills in the context of sustainable food systems. If you agree to be in this research study, you allow us to use your responses in the questionnaires and assignments from the sustainable food systems learning experience to conduct a research study. The questionnaires ask questions about your experiences in food, agriculture, and environmental education, your thoughts about food systems and future applications, and your opinions about the learning experiences. The pre-test and post-test questionnaires will take 10 to 20 minutes respectively. If you are asked to participate in the voice-recorded interviews, it will be once in February and once in April during the study period for 30-45 minutes each time.

Being in this study is voluntary. You can ask questions that you may have about this study at any time. If you do not want to be in this study or at any point you decided not to continue after you have started, just let me know. This study is confidential.

Signing this paper means that you have read this and that you agree to be in this study. Remember, being in this study is up to you. Whatever you decide will not affect your grade or your relationships with the teacher or anyone at Purdue University.

If you have any questions regarding this study, you may contact Dr. Neil Knobloch at (765) 494-8439 or email (nknobloc@purdue.edu) or Mingla Charoenmuang at (818) 416-1831 or email (mcharoen@purdue.edu). If you have questions about your rights while taking part in the study or have concerns about the treatment of research participants, please call the Human Research Protection Program at (765) 494-5942, email (irb@purdue.edu) or write to:
Human Research Protection Program - Purdue University,
Ernest C. Young Hall, Room 1032
155 S. Grant St., West Lafayette, IN 47907- 2114

I, ____________________________________, want to be in this research study.
(write your name here)

______________________________________ _____ ___________________________
Participant's Name Date

RESEARCH PARTICIPANT CONSENT FORM

High School Students' Systems Thinking Skills in the Context of Sustainable Food Systems

Principal Investigator: Neil Knobloch, Ph.D., Professor
Department of Agricultural Sciences Education and Communication
Purdue University

Key Information

Please take time to review this information carefully. This is a research study that aims to collect data from a 15-session learning experience over the course of 6 weeks. The goal of this project is to promote systems thinking among high school students and to improve the instruction of systems thinking in the food-related context. Systems thinking is important for students in solving complex problems and become a responsible citizen. Your participation in this study is voluntary which means that you may choose not to participate at any time without penalty or loss of benefits to which you are otherwise entitled. You may ask questions to the researchers about the study whenever you would like. If you decide to take part in the study, you will be asked to sign this form, be sure you understand what you will do and any possible risks or benefits. Additional explanations may be more detailed in the sections below.

What is the purpose of this study?

This study is part of the project that provides a sustainable food systems learning experience taking place in 15 sessions of the food science class. The purpose of this study is to explore and describe high school students' systems thinking skills before and throughout the sustainable food systems learning experience, which is designed for students to practice system thinking skills. Further, the researcher seeks to explore how the learning experience will help students practice systems thinking and how students intend to use systems thinking beyond the learning experience.

You are being asked to participate in this study as the teacher who implements this learning experience. We would like to enroll all 15 students of this class and you as their teacher in this study.

What will I do if I choose to be in this study?

You will be asked to:

1. Implement a 15-session learning experience during February to April
2. Provide voice-recorded feedback and comments from their observations throughout the learning experience as another data source
3. Facilitate with data collection

Data that will be collected in this study included: a background survey questionnaire and a feedback questionnaire, assignments, interviews, researchers' field notes, and teacher's feedbacks and comments.

How long will I be in the study?

15 class sessions in February and April.

What are the possible risks or discomforts?

The research risk is no greater than everyday activities. Breach of confidentiality is always a risk with data, but we will take precautions to minimize this risk as described in the confidentiality section.

APPENDIX C. QUESTIONNAIRES

Background Survey Questionnaire

Section I. Getting to Know You

Instructions: Please select the appropriate response for each statement.	**Never**	**Once a Year**	**Once a**	**Once a**	**Every day**
1. How often do you learn about agriculture outside of school (e.g., video, podcast, FFA, 4-H, farm simulator)?	1	2	3	4	5
2. How often do you learn about environmental topics outside of school (e.g., summer camp, Envirothon)?	1	2	3	4	5
3. How often do you visit a farm?	1	2	3	4	5
4. How often do you go shopping for food?	1	2	3	4	5
5. How often do you visit a farmers' market?	1	2	3	4	5
6. How often do you cook?	1	2	3	4	5

Section II. About You

Instructions: Please select the appropriate response for each statement.	**Strongly Disagree**	**Disagree**	**Agree**	**Strongly Agree**
1. I am interested in pursuing a career related to food production or agriculture.	1	2	3	4
2. I am interested in pursuing a career related to food processing.	1	2	3	4
3. I am interested in pursuing a career related to natural resources or environmental studies.	1	2	3	4
4. I am interested in knowing which of the foods I eat are produced or grown in Indiana.	1	2	3	4
5. I am <u>not</u> concerned about whether the food I eat comes from nearby or far away.	1	2	3	4
6. I bring a reusable bag to the store for food shopping.	1	2	3	4
7. For the most part, I have healthy eating habits.	1	2	3	4
8. I am comfortable identifying components in a system.	1	2	3	4
9. I understand the concept of sustainability.	1	2	3	4

Section III. Personal Opinions

Instructions: Please indicate your personal opinions by selecting the appropriate response for each statement.	**Strongly Disagree**	**Disagree**	**Agree**	**Strongly Agree**	**I Don' t Know**
1. A food system is a complex system.	1	2	3	4	0
2. A system that loses a part of itself is still the same system.	1	2	3	4	0
3. Our food production does not have an impact on the environment.	1	2	3	4	0
4. Most farmers take the food they grow directly to supermarkets where it is sold.	1	2	3	4	0
5. What we choose to eat has little to no impact on the environment.	1	2	3	4	0
6. The loss of biodiversity is a problem related to the food system.	1	2	3	4	0
7. Most farmers change their production practices to produce food that consumers want.	1	2	3	4	0

Section IV. Systems Thinking

Instructions: Please select the appropriate response for each statement.	**Strongly Disagree**	**Disagree**	**Agree**	**Strongly Agree**
1. I value other people's opinions of the situation.	1	2	3	4
2. I look beyond a specific event to determine the cause of the problem.	1	2	3	4
3. I think of the problem as a series of connected issues.	1	2	3	4
4. I think that systems are constantly changing.	1	2	3	4
5. I keep in mind that proposed changes can affect the whole system.	1	2	3	4
6. I think small changes can produce important results.	1	2	3	4
7. I recognize system problems are influenced by past events.	1	2	3	4
8. I consider that the same action can have different effects over time, depending on the state of the system.	1	2	3	4

Section V. Demographic Information

1. Gender: ☐ Male ☐ Female ☐ Prefer not to answer
2. What is your grade level? ☐ 9th ☐ 10th ☐ 11th ☐ 12th
3. Do you farm or garden? ☐ No ☐ Yes, please explain___________________________
4. Have you learned about sustainability?

   ☐ No

   ☐ Yes, from ☐ parents

   ☐ teachers

   ☐ media

   ☐ other, please specify__________________________

   How would you define sustainability?

   ____
5. Please choose your ethnicity (check all that apply):

   ☐ Black/African American

   ☐ White, Caucasian, European, Not Hispanic

   ☐ Alaska Native

   ☐ Native Hawaiian/Pacific Islander

   ☐ American Indian/ Native American

   ☐ Asian/Asian American

   ☐ Mexican-American, Chicano, Hispanic, Latino
6. Are you eligible for free/reduced price meals? ☐ Yes ☐ No

Thank you for completing this questionnaire!

Feedback Questionnaire

Section I. About You

Instructions: Please select the appropriate response for each statement.	**Strongly Disagree**	**Disagree**	**Agree**	**Strongly Agree**
1. I am interested in pursuing a career related to food or agriculture.	1	2	3	4
2. I am interested in pursuing a career related to environmental studies.	1	2	3	4
3. I am interested in knowing which of the foods I eat are produced or grown in Indiana.	1	2	3	4
4. I am <u>not</u> concerned about whether the food I eat comes from nearby or far away.	1	2	3	4
5. I bring a reusable bag to the store for food shopping.	1	2	3	4
6. For the most part, I have healthy eating habits.	1	2	3	4
7. I am comfortable identifying components in a system.	1	2	3	4
8. I understand the concept of sustainability.	1	2	3	4

Section II. Personal Opinions

Instructions: Please indicate your personal opinions by selecting the appropriate response for each statement.	**Strongly Disagr**	**Disagree**	**Agree**	**Strongly Agree**	**I Don't**
1. A food system is a complex system.	1	2	3	4	0
2. A system that loses a part of itself is still the same system.	1	2	3	4	0
3. Our food production does not have an impact on the environment.	1	2	3	4	0
4. Most farmers take the food they grow directly to supermarkets where it is sold.	1	2	3	4	0
5. What we choose to eat has little to no impact on the environment.	1	2	3	4	0
6. The loss of biodiversity is a problem related to the food system.	1	2	3	4	0
7. Most farmers change their production practices to produce food that consumers want.	1	2	3	4	0

Section III. Systems Thinking

Instructions: Please select the appropriate response for each statement.	**Strongly Disagree**	**Disagree**	**Agree**	**Strongly Agree**
1. I value other people's opinions of the situation.	1	2	3	4
2. I look beyond a specific event to determine the cause of the problem.	1	2	3	4
3. I think of the problem as a series of connected issues.	1	2	3	4
4. I think that systems are constantly changing.	1	2	3	4
5. I keep in mind that proposed changes can affect the whole system.	1	2	3	4
6. I think small changes can produce important results.	1	2	3	4
7. I recognize system problems are influenced by past events.	1	2	3	4
8. I consider that the same action can have different effects over time, depending on the state of the system.	1	2	3	4

Section IV. The Food Systems Thinker Learning Experience

Instructions: Please indicate your personal opinions by selecting the appropriate response for each statement.	**Strongly Disagree**	**Disagree**	**Agree**	**Strongly Agree**
1. I can use what I learn in this learning experience.	1	2	3	4
2. I developed the ability to think in systems thinking way.	1	2	3	4
3. I think online lessons provided an effective learning experience.	1	2	3	4
4. Worksheets effectively helped me learn the online lessons.	1	2	3	4
5. I liked learning from examples in Indiana.	1	2	3	4
6. Interacting with guest speakers was valuable to me.	1	2	3	4
7. Volunteering at the food pantry was valuable to me.	1	2	3	4
8. Visiting the diversified organic farm was valuable to me.	1	2	3	4
9. This learning experience gave me skills and techniques directly applicable to my future career.	1	2	3	4
10. This learning experience effectively challenged me to think.	1	2	3	4
11. I have a greater understanding of how my food choices are related to the food systems as a whole.	1	2	3	4
12. I'd recommend this learning experience.	1	2	3	4

Section V. Looking into the Future

1. In the future, when you make decisions to purchase food, what factors will influence your decision?

Instructions: Please select the appropriate response at the right of each statement.	**Not At All**	**A Little**	**Somewhat**	**A Lot**	**Absolutely**
1. Family tradition	1	2	3	4	5
2. Desire to save money	1	2	3	4	5
3. Desire to support local farmers and businesses	1	2	3	4	5
4. Concern about my health and safety	1	2	3	4	5
5. Concern about profitability of small-scale farmers	1	2	3	4	5
6. Concern about limited natural resources	1	2	3	4	5
7. Concern about global climate change	1	2	3	4	5
8. Concern about pollution	1	2	3	4	5
9. Desire to reduce dependence on foreign energy sources	1	2	3	4	5
10. Other, please specify:___________________________	1	2	3	4	5

2. How would you apply systems thinking in everyday life? (Thinking of things as a system that has components and relationships interacting with each other.) Please briefly explain.

____

____

____

____

Section VI. Additional comments.

____

____

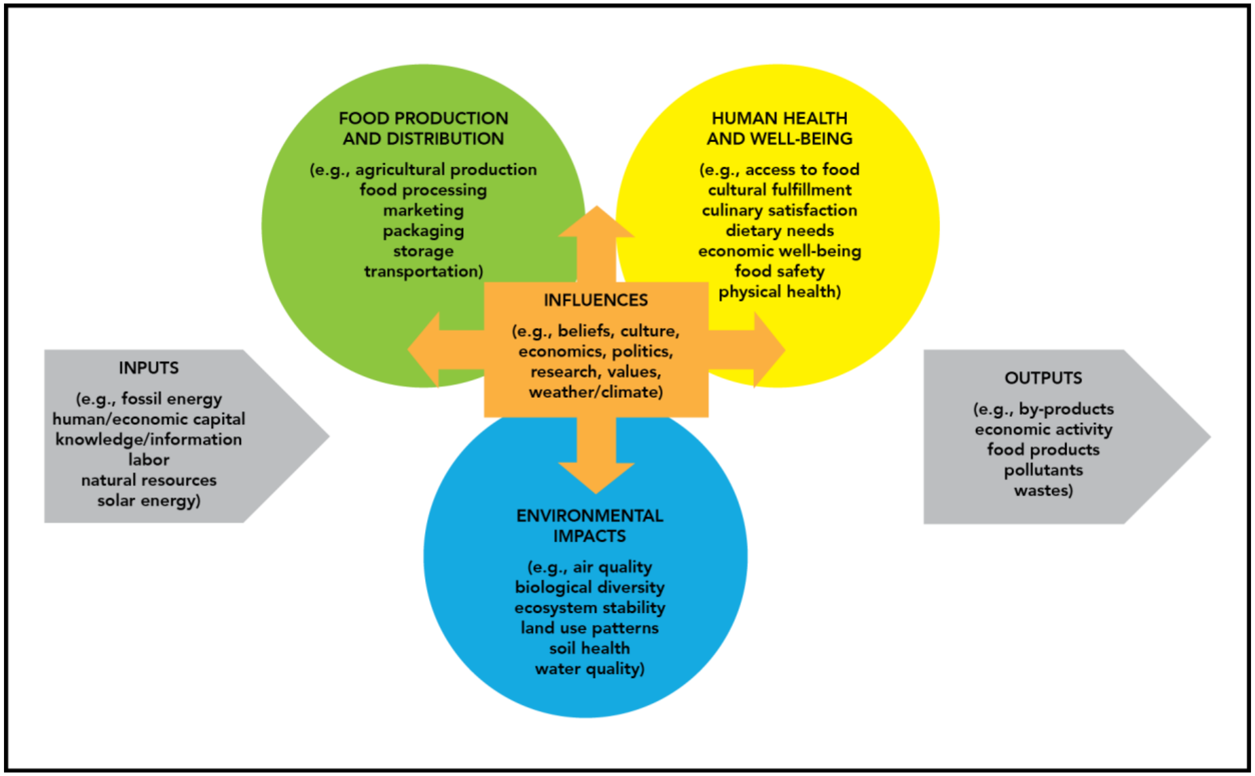
____

Thank you for completing this questionnaire!

APPENDIX D. APPLESAUCE ASSIGNMENT

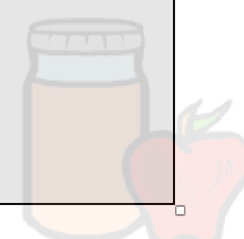
Systems thinking is seeing things being connected to each other and identifying the components and the relationships between them over time.

Explain how the life of applesauce from growing an apple tree until throwing away a container are relevant to each topic in the diagram to express your systems thinking. Use as many examples provided for each topic as you can. If you do not find that they are relevant, please explain why.



	Growing Apples	Processing Applesauce	Consuming Applesauce
Inputs		*Fossil energy*: Uses to transport apples from farm to factory *Economic capital*: Investment in technology to get desirable applesauce consistency *Knowledge*: Permitted food additives *Labor*: Operate the apple grinder machine *Natural resource*: Apple, water, sugar *Solar energy*: Could dry and lower quality of applesauce. Keep out of direct sunlight.	
Production & Distribution			
Human Health & Well-being			

	Growing Apples	Processing Applesauce	Consuming Applesauce
Environmental Impacts			
Influences			
Outputs			



APPENDIX E. STUDENT INTERVIEW PROTOCOL

Before the learning experience

- Could you tell me more about your previous experiences with food and agriculture?
- What do you think of when you decide what to eat?
- What do you think of when you decide what food you would buy at the grocery store?
- (Use the applesauce assignment), could you explain what you meant by this?
- What was challenging to complete the applesauce assignment? What could have helped make it easier?
- In your own words, what does the term "food systems" mean?
- If someone asks you, 'what is sustainable food systems?', what will you tell them? What are the differences of sustainable food systems and other food systems?

After the learning experience

- What is your favorite part of this learning experience? Why?
- What is your least favorite part of this learning experience? Why?
- What are some suggestions you have to improve this learning experience?
- How is this program useful to you? How can you use what you learned in everyday life?
- How do you feel about thinking of things as a system?
- In your own words, what does the term "food systems" mean?
- In your own words, what is sustainable food systems?
- How would systems thinking or thinking of things as a system benefit you in the future?
- What would you do to help make food systems more sustainable? Why do you think that?

APPENDIX F. TALKING POINTS WITH TEACHER

- Did the students comment on the learning experience to you? What do they think?
- What are your comments on the learning experience?
- How could the online lessons be improved?
- How could the learning experience be improved?
- Did you find the usefulness of the experience? Please explain.
- What are your observations on the students’ level of engagement?

APPENDIX G. WORKSHEETS

Food Systems Thinker

Food Systems Thinker Worksheet

Lesson 1.1 A Whole and Its Components

Activity: Relationships in the Modern Food Systems

STEP 1. Choose ONE of these food items: Bag of frozen peas, bag of potato chips, box of raisins, or bag of popcorn.

I choose ______________________________________.

STEP 2. Choose FIVE processes of food systems that are related to your chosen food item.

P1. ______________________________

P2. ______________________________

P3. ______________________________

P4. ______________________________

P5. ______________________________

Growing	Distribution
Food Processing	Retailing
Packaging	Shopping
Label Making	Disposal

STEP 3. Identify components needed for your chosen food item in each process (examples on website)

Processes	Components
P1. ____________________________	
P2. ____________________________	
P3. ____________________________	
P4. ____________________________	
P5. ____________________________	

1

STEP 4. Write sentences that describe the relationships of components and processes focusing on the process.

Example: Distribution- A truck driver transports tomatoes from the farm and labels from a factory to a food processing plant, and empty cans to a recycling facility.

R1. ____

____

R2. ____

____

R3. ____

____

R4. ____

____

STEP 5. Write sentences that describe the relationships of components and processes focusing on the components.

Example: Water is needed in growing tomatoes, processing tomato sauce, making paper for labels, and recycling process. Truck drivers need to drink water during distribution.

R5. ____

____

R6. ____

____

R7. ____

____

R8. ____

____

Reflection Questions

1. What are two important relationships in the food system that you think every consumer should know about? Why do you think so?

Relationship 1____

Because____

Relationship 2____

Because____

2. What are some benefits to see that things are connected to each other?

3. What do you find useful about the lesson today? How could this lesson be improved?

Useful____

To be improved____

Food Systems Thinker Worksheet
Lesson 1.2 Levels of Food Systems

Activity 1: Resilience and the Levels of Food Systems with Mary Lutz

1. Where would you get food from if all the stores in the area were closed?

____

2. Name two things that can disrupt food from traveling to your grocery stores.

____

3. What are the sizes of your three balloons (add up to 100%)? Draw in the space provided.

Economic ____/100%	Environmental ____/100%	Social ____/100%

4. What were three things Mary suggested you could do to prevent your rubber band of food resilience from breaking?

1. ____

2. ____

3. ____

Activity 2: Six Levels of Food Systems

Match the words in the left-hand column with the appropriate phrase in the right-hand column.

1) Individual
2) Household
3) Local
4) Regional
5) National
6) Global

a) a boundary to analyze self-resilience within a state or a cluster of states
b) a boundary to analyze direct-to-retailer sales
c) a boundary to analyze U.S. imports of food products
d) a boundary to analyze the influence of eating behaviors of parents to their children
e) a boundary to analyze whether a person can afford food
f) a boundary to analyze the label regulation

Activity 3: Boundaries are arbitrary.

No single definition of "local" or "local food systems" exists. The geographic distances between production and consumption varies.

Google three sources or ask three people:
"What is considered local food to you? What is not local?"

Source	Local food boundary
	Include: Exclude:
	Include: Exclude:
	Include: Exclude:

Reflection Questions

1. What do you include and exclude in your boundary of local food?

Include____

____

Exclude____

____

2. What are three things you could do to be more food resilient?

2.1 ____

2.2 ____

2.3 ____

3. What do you find useful about the lesson today? How could this lesson be improved?

Useful____

____

To be improved____

____

Food Systems Thinker

Food Systems Thinker Worksheet

Lessons 1.3 Interactions of Food Systems with Other Systems

Activity 1: ExxonMobil clip

1. Memory game: What are things and activities that the video clip shows or mentions? Compare your answers with a classmate.

   In the kitchen____

   ____

   At the oil drilling operation____

   ____

   At the egg factory____

   ____

   During transportation____

   ____

   At the grocery store____

   ____

2. "You don't need to think about the energy that makes our lives possible, because we do." What are consequences of thinking and not thinking about the energy that you use?

   If you think about energy you use, ____

   ____

   If you don't think about energy you use, ____

   ____

Activity 2: Food systems and other systems

Which system(s) in the slideshow have you not thought of before? ________________________

Activity 3: The interview with Gary Cox

What influences or could have influenced the operation at Trinity Acres Farm?
Provide an example for each system with a brief explanation.

Cultural Systems

<u>Example</u> Customs: Gary mainly grows what he likes and what he's used to eating growing up.

Climate Systems

Health Systems

Ecosystems

Economic Systems

Political Systems

Reflection Questions

4. Explain the changes and what you think would happen.

    a. In what ways, can changes in food systems affect changes in climate systems?

____

____

    b. In what ways, can changes in climate systems affect changes in food systems?

____

____

5. Think of a trip from your home to a grocery store as a system.
   What are three systems that interact with the system of the trip from your home to a grocery store? Briefly explain the influence the systems have on each other.

2.1____

2.2____

2.3____

6. What do you find useful about the lesson today? How could this lesson be improved?

Useful____

____

To be improved____

____

Food Systems Thinker Worksheet
Lesson 2.1 Key Players

Activity 1: Actors in the Food Systems

1. Based on the slides, which role in the food systems are you most interested in doing? Why?

____

____

2. Choose an actor. How could you make their role in the food systems easier?

Example Decomposers and detritivores. I will not put coated paper or sticky labels in the compost pile because they contain toxins and can harm the decomposers and detritivores.

Actor____

What you could do____

____

3. Name one more actor in the food systems not mentioned in the slides. What is/are their role(s) in the food systems?

Actor____

Role(s)____

____

Activity 2: The Interview with Dr. Foster

1. What are three strategies to protect the pollinators?

1.1 ____

1.2 ____

1.3 ____

2. What is an example for each sustainability pillar that Dr. Foster uses to support sustainability in his bee keeping business?

   Economic ____

   Environmental____

   Social/Cultural____

3. What is the consumers' role in determining how farmers produce food?

   ____

   ____

4. Briefly explain how working at the university and at the apiary give Dr. Foster different perspectives or points of view.

   ____

   ____

Activity 3: Farm Workers

1. What are three hardships that the migrant farmworkers experience?

   1.1____

   1.2____

   1.3____

2. How would the boycotts and strikes help the farmworkers?

   ____

   ____

3. How would you handle the situation if you were in their shoes?

   ____

   ____

Reflection Questions

1. After finishing high school, what is your desired future career? What are the connections of this career with food systems?

Your desired career____

Connections with food systems____

____

2. Why is it important to look at things from a different perspective?

____

____

____

3. What do you find useful about the lesson today? How could this lesson be improved?

Useful____

____

To be improved____

____

Food Systems Thinker Worksheet
Lesson 2.2 The Influencing Forces

Activity 1: Fear of Tomatoes

Variables are anything that can change over time. Provide an example for the following variables that made people in Europe stop fearing tomatoes and eating them instead?

Belief: ____

Value: ____

Culture: ____

Knowledge: ____

Activity 2: Read "The Food Pyramid of the Future" and answer the questions below.

1. What are three major differences between MyPlate and Harvard's Healthy Eating Plate?

   1.1____

   1.2____

   1.3____

2. Draw and label a food guide for yourself with suggestions for healthy eating and healthy environment.

Activity 3: What the World Eats

1. The slideshow presents many variables. For example, ages of family members, locations, types of food available in the area, family's favorite foods. List two more:

   1.1______________________________

   1.2______________________________

2. Compare a family that pays less than $50 and a family that pays more than $100.

	Family 1	Family 2
Family Name		
City and Country		
Number of family members		
Food expenditure for one week (in US dollars)	(less than $50/week)	(more than $100/week)
More processed foods or fresh foods in the picture?		
Which one has more variety of foods?		

2.1 Why is there a huge difference of how much these two families paid for foods?

____

____

2.2 How did the locations influence the food choices each family had?
(Hint: Use the map or search about the country's food production.)

Family 1____

____

Family 2____

____

____

Reflection Questions

1. If you lived in the same country as the family that pays less than $50/week, how will your food be the same or be different from now? Why?

____

____

____

2. How does 2-hour delay influence your breakfast, lunch, snack, or dinner? (variable1 = the time that school starts, variable2 = your eating routine)

____

____

____

3. What do you find useful about the lesson today? How could this lesson be improved?

Useful____

____

To be improved____

____

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Food Systems Thinker

Food Systems Thinker Worksheet

Lesson 2.3 Impact of Food Systems

Activity 1: Inputs & Outputs in the Food Systems

1. Fill in the blanks with the inputs provided.

Feed	Water	Energy	Transport
Equipment	Chemicals	Material	

1.1 In agricultural growing, __________ is used for irrigation, pesticide and fertilizer applications, crop cooling, and frost control.

1.2 __________ is food grown or developed for livestock and poultry.

1.3 In distribution, forklift is an important __________ used to lift and move materials over short distances.

1.4 __________ used in food packaging include glass, metals, paper, and plastics.

1.5 Retailers need to use a lot of __________ to keep a constant temperature in the refrigeration displays and units.

1.6 Food industry adds ___________ as food preservatives to fight spoilage caused by bacteria, molds, fungus, and yeast.

1.7 Foods move to market by means of __________of air, water, and land.

2. Let's play Jeopardy of outputs in the food systems!

Air emissions	Wastewater	Solid waste

2.1 Garbage, refuse, and sludge from a wastewater treatment plant at the factories.

What is ____________________ ?

2.2 Gases and particles which are put into the air by pesticide sprayers, food processing machinery, and trucks.

What are ____________________ ?

2.3 Water affected by human use such as runoff, chilling, washing, and flushing toilet.

What is ____________________ ?

3. Match inputs and outputs in the left-hand column with the phrases or sentences stating negative impacts on health and the environment in the right-hand column. (Bonus points for making multiple matches.)

7) Water	g) Irritate(s) airway, cause(s) respiratory problems and fatigue.
8) Energy	h) Can be pesticides, fertilizers, and high concentrations of antibiotics and hormones, which can cause the loss of biodiversity. (biodiversity = variety of life living in an area)
9) Chemicals	i) Use(s) energy from fossil fuels and produce(s) greenhouse gases contributing to climate change.
10) Transport	j) Pack(s) landfills, produces greenhouse gas, and pollutes groundwater with leachate (contaminated liquid).
11) Equipment	k) Intensive use of _______ in industrial farms results in short supplies of drinking water.
12) Air Emissions	l) Cause(s) air and noise pollution. (pollution = harmful substance or energy introduced to the environment)
13) Wastewater	m) Can come from fossil fuels such as oil, coal, and natural gas which the extraction process can destroy natural habitats.
14) Solid waste	n) Flow(s) into lake, river, and stream causing algal bloom.

(Bonus) What can be paired with more than one? Explain why.

____

____

4. Both inputs and outputs can have an impact on health and the environment. How could sustainable food systems address this problem?

____

____

____

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Activity 2: Fill the stock-and-flow diagram based on the stock for each diagram.

Individual level

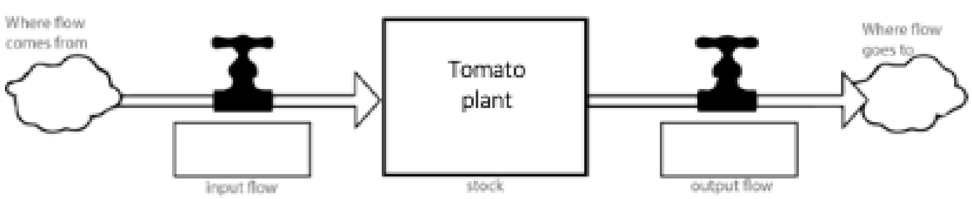
Restaurant	Toilet	Pizza	Poop

Household level

You	Supermarket	Tomato	Pizza

Farm level

Farmers' market or grocery store	Tomato	Compost or Fertilizer	Compost pile or farm supply store



Atmospheric level

Pizza sauce factory and Trucks	Methane and CO_2	Forests and Oceans	Methane and CO_2

Reflection Questions

7. Think of another example for stock and flow that was not included in this lesson. What is the stock? What are the input flow and output flow? Where does the input come from? Where does the output go to?

____

____

____

8. Why does what we choose to eat has an impact on the environment?

____

____

____

9. What do you find useful about the lesson today? How could this lesson be improved?

Useful____

____

To be improved____

____

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Food Systems Thinker

Food Systems Thinker Worksheet

Lesson 3.1 Food Waste

Activity 1: Why do we waste perfectly good food in the U.S.?

5. Watch the video and respond to the questions below.

   1.1 How do "freegans" check that the food they rescue is still good?

   ____

   5.1 Why do grocery stores throw away unexpired food?

   ____

   5.2 How can you encourage businesses and other people to donate food to charities?

   ____

   5.3 After the expiration date, what should you do before throwing the food away?

   ____

   5.4 How can you reduce food waste in your own home?

   ____

6. From your personal experience, what are the reasons that you throw away food?

   ____

   ____

   ____

7. In your opinion, what will the future be like if a large amount of food continues to be wasted?

   ____

   ____

   ____

8. Think of an example of how making a small change can result in a large improvement in the whole system.

____

____

Activity 2: You are in control of how much you get food as well as where food you do not use and the leftovers will go. Use the hierarchy diagram and tips from the video in Activity 1 to help you plan to reduce food waste at school and at home.

1. List three things you could do to reduce food waste at school and at home.

   1. ____

   2. ____

   3. ____

2. Apply what you learned in this lesson and the previous lessons. How can reducing food waste benefit your health, economy, environment, and community?

   Health: ____

   Economy: ____

   Environment: ____

   Community: ____

Reflection: What do you find useful about the lesson today? How could it be improved?

Useful____

____

To be improved____

____

Food Systems Thinker

Food Systems Thinker Worksheet

Lesson 3.2 Climate Change and Biodiversity

Activity 1: Understanding climate change.

1. What are the differences between weather and climate?

   ____

2. What become more frequent or more intense with human-induced climate change?

   ____

3. How could climate change affect your food systems?

   ____

Activity 2: Understanding time delays.

1. What are the examples of short-term and long-term consequences provided?

   Short-term: ____

   Long-term: ____

2. Think of other short-term and long-term consequences in your experience.

   Short-term: ____

   Long-term: ____

3. What is the link between the industrial age and climate change?

   ____

   ____

4. Because of the delays, we are not yet experiencing the full consequences of past greenhouse emissions. In your opinion, what should you, as a consumer, do to make sure that the climate change will not get worse? Be specific.

   ____

   ____

Activity 3: Talking about biodiversity with John Sherck.

3. What are the things you like to eat that are commonly grown in your region?

   ____

4. What are the things you like to eat that are NOT commonly grown in your region?

   ____

5. What were the two variables that influenced John's decision of what to plant?

   ____

6. How did climate change affect John's farm?

   ____

7. How did John use biodiversity to benefit his diet?

   ____

8. How did John use biodiversity to lessen the impact of extreme weather conditions?

   ____

Reflection

1. Apply what you have learned to explain how John and what he does help reduce greenhouse gas emissions.

   ____

   ____

2. What do you find useful about the lesson today? How could it be improved?

   Useful____

   ____

   To be improved____

   ____

Food Systems Thinker

Food Systems Thinker Worksheet

Lesson 4.1 I Am a Consumer and Citizen

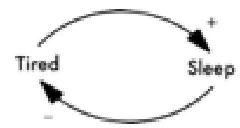
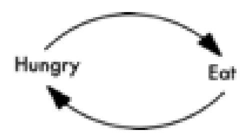
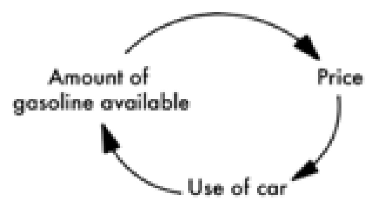
Activity 1: Learning about feedback.

STEP 1 Complete the sentences to form cause-and-effect relationships.

STEP 2 Label feedback loop diagrams using + and - symbols.

A + indicates the variable at the head of the arrow changes in the same direction as the variable at the tail of the arrow. (When the variable at the arrow head goes up, the variable at the arrow tail also goes up OR when the variable at the arrow head goes down, the variable at the arrow tail also goes down.)

A - indicates that the variables change in opposite directions (When the variable at the arrow head goes up, the variable at the arrow tail goes down OR When the variable at the arrow head goes down, the variable at the arrow tail goes up).

Example	Being tired causes me to sleep. Sleeping causes me to feel less tired.	
1.1	STEP 1 Complete the sentences. Being hungry causes me to _____________. _________causes me to _________________.	STEP 2 Label the diagram with + and - symbols. 
1.2	STEP 1 Circle the logical answers. A gasoline shortage causes the gas price to ___go down ___/___go up___. When the gas price is _low_/_high_, people use their car _less_/_more_. When people use their car _less_/_more_, _less_/_more_ gasoline is available.	STEP 2 Label the diagram with + and - symbols. 

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Activity 2 and 3: Supporting a sustainable food system.

Explain things from the list that you've already been doing. If you are not already doing this, explain how you will try to do it in the future.

To do list	Are you doing this?	Explain how you've done this or how you'll try to do this in the future.
1. Eat food grown or raised locally when possible.		
2. Eat whole foods instead of processed, packaged foods.		
3. Preserve food by canning, drying, and freezing foods.		
4. Use reusable containers to avoid wasteful packaging.		
5. Promote healthy food and environment.		

Reflection

1. Using the concept of feedback, how does eating food grown or raised locally support a sustainable food system?

____

____

2. Using the concept of feedback, how does using reusable food containers promote a healthier environment?

____

____

3. What do you find useful about the lesson today? How could it be improved?

Useful____

____

To be improved____

____

Food Systems Thinker

Food Systems Thinker Worksheet

Lesson 4.2 Working Together

Activity 1: Lawrence Community Gardens addressing food insecurity.

1.1 Why did Sharrona start the community garden project?

____

____

1.2 What does a 'food desert' look like?

____

____

1.3 How have the Lawrence Community Gardens helped people in the community?

____

____

1.4 Learning from this video, what is a project you could do to support a more sustainable food system in your community? Briefly explain.

____

____

Activity 2: Learning about time horizon.

2.1 How long it might take you to see the impact of the project you answered in 1.4? What would it depend on?

____

____

Reflection: What do you find useful about the lesson today? How could it be improved?

Useful____

To be improved____

End of Program Reflection

You have practiced systems thinking throughout the program to recognize relationships in food systems and that everything comes from somewhere and goes somewhere. You also learned about feedback in a system and there may be a delay in a system.

How would you apply systems thinking to choose what food you will buy and eat from now on?

____

____

____

____

____

____

____

How can thinking of food as a system help you support a food system to become more sustainable?

____

____

____

____

____

____

____

APPENDIX H. STUDENTS' LEARNING OUTCOMES

Students were asked to complete pre- and posttest questionnaires to monitor their learning outcomes using a Likert-type scale: 1 = strongly disagree; 2 = disagree; 3 = agree; and 4 = strongly agree (see Table A). In terms of their behaviors as a responsible consumer, four items (e.g., I am interested in knowing which of the foods I eat are produced or grown in Indiana; I am concerned about whether the food I eat comes from nearby or far away; I bring a reusable bag to the store for food shopping; and for the most part, I have healthy eating habits.) were calculated for a mean. Students were also asked about their understanding about the concept of sustainability and their comfort level in identifying parts. The score about students' knowledge about food systems were calculated for a sum with items 2 to 5 in this section being reverse-coded. Lastly, eight items from the Systems Thinking Scale (Ateskan & Lane, 2018; Moore et al., 2010) were adapted and selected to explore students' dimensions of systems thinking through self-report. In this study, the reliability check with Cronbach's *alpha* resulted in the score of 0.92 for pretest and 0.94 for the posttest (N = 12) by using SPSS.

Table A: Students' Learning Outcomes Before and After the Learning Experience

Pseudonym	Responsible Consumer		Understanding Sustainability		Comfortable Identifying Parts		Food Systems Knowledge		Systems Thinking Scale	
	Pre	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**
Apricot	2.00	1.75	1.00	4.00	3.00	4.00	25.00	26.00	32.00	32.00
Arugula	2.50	2.50	1.00	3.00	3.00	3.00	12.00	21.00	23.00	24.00
Blueberry	3.00	2.75	3.00	3.00	2.00	3.00	21.00	21.00	17.00	26.00
Edamame	2.75	2.50	3.00	2.00	3.00	3.00	20.00	18.00	16.00	19.00
Ginger	2.25	2.50	3.00	3.00	3.00	3.00	21.00	20.00	24.00	24.00
Jujube	2.25	2.50	3.00	3.00	3.00	3.00	21.00	23.00	30.00	31.00
Jalapeño	1.75	2.25	4.00	4.00	4.00	4.00	24.00	27.00	28.00	30.00
Kale	2.75	2.50	4.00	3.00	4.00	2.00	5.00	18.00	30.00	30.00
Kiwi	1.75	2.00	2.00	3.00	3.00	3.00	20.00	24.00	23.00	25.00
Nectarine	2.75	3.00	4.00	4.00	3.00	4.00	21.00	19.00	26.00	28.00
Raspberry	3.00	3.25	3.00	2.00	3.00	3.00	14.00	19.00	26.00	24.00
Spinach	2.25	2.75	1.00	2.00	3.00	N/A	14.00	9.00	19.00	16.00

VITA

Mingla Charoenmuang was born in DeKalb, Illinois and grew up in Chiang Mai, Thailand. She is very passionate about sustainable food systems and environmental protection topics. She earned a Bachelor of Science in Environmental Science from Chulalongkorn University in Bangkok and a Master of Arts in Environmental Education from Goshen College in Indiana. Mingla started her professional career as an assistant field instructor in Northern Thailand. She has since broadened her interest in sustainable food systems by teaching outdoor education and working on organic farms. Before joining Purdue University, Mingla served as the Community Food Systems Coordinator through AmeriCorps VISTA program at Vermont Technical College. She ran various projects to fight against poverty and improve environmental conditions through promoting sustainable food systems education.

Under the mentorship of Dr. Neil Knobloch, Mingla gained teaching, engagement, and research experiences in learner-centered teaching, STEM integration, and food insecurity topics. Mingla developed several educational resources for various age groups. For example, she developed experiential learning assignments for the Nexus of Food & Nutritional Security, Hunger, and Sustainability graduate course offering to four universities, designed three youth programs to teach about climate change and gardening skills for local children ages in preschool to third grade, and created agroecosystems lesson plans for high school teachers. Upon graduation, Mingla wishes to continue her contribution to the effort of making this world a better place by promoting and improving human and environmental health through food systems education.

Follow Instagram and Facebook @FoodSystemsThinker to learn more about her projects and to access the sustainable food systems curriculum.

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