EXPLORATION OF PURDUE EXTENSION MASTER GARDENER VOLUNTEERS' SCIENTIFIC THINKING AFTER PARTICIPATING IN AN INQUIRY-BASED HOME HYDROPONICS PROJECT

By

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Dedicated to the Almighty God and to all my family

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ABSTRACT

The effects of science have remarkably changed our world and we should learn how to live effectively in a consistently evolving world. Scientific thinking is believed to be the key factor in developing the ability to use scientific knowledge in problem-solving (Norris & Philips, 2003; Zimmerman, 2000). Therefore, increasing adults' ability to think scientifically would help them apply better problem-solving strategies in everyday routines. Unfortunately, not a lot has been done on advancing scientific thinking education among adults in formal and nonformal educational settings in the U.S. (Osborn, 2013). Hence, this study used case study approach, a qualitative research method, to explore Purdue Extension Master Gardener volunteers' scientific thinking in the context of problem-solving through inquiry. The purpose of this study was to explore Purdue Extension Master Gardener volunteers' scientific thinking throughout a home hydroponics inquiry-based project and to describe their experiences to complete the learning module. This study took over nine weeks of a virtual inquiry-based learning program with four Purdue Extension Master Gardener volunteers. Data collection included pre- and post-interview, project worksheets and exit notecards at the end of each online lesson.

There were three major findings. First, participants demonstrated scientific thinking skills by conducting experiments and acknowledging the effectiveness of scientific inquiry in problem-solving. Second, participants' learning experiences were positive following the integration of adult learning theory assumptions into the learning module. Third, participants expressed intent to continue using scientific experiments to solve their gardening problems as a new skill they learned and found effective in helping them understand and solve problems. The findings of this study suggest that both domain-specific (prior knowledge and everyday life experience) and domain-general (scientific methods and reasoning processes) strategies are important to conduct scientific

reasoning. In addition, motivation is a critical factor that drives the direction of inquiry, hypothesis, and helps in persisting to finish up the experiments. The findings also suggested that adults learn best when they have independence and self-direction in working on topics that align with the real-world problem-solving directly linked to their everyday life.

The findings of this study suggest that developing scientific thinking increases the ability of adults to appreciate valuable information, evaluate data source, and increase informed citizenry in general. Also, for teaching adults, instructors and instructional designers should concentrate on topics that have direct impact on adults' life, mainly focusing on real-world problem-solving. Future studies could consider exploring scientific thinking using a different context than problem-solving used in this study. Future studies also should consider using larger populations with a variety of backgrounds to assess the role of prior knowledge in scientific thinking development.

CHAPTER 1. INTRODUCTION

1.1 Overview

Science, alongside art and literature are mostly considered peculiar characteristics of the human species (Dunbar & Klahr, 2012). The effects of science have remarkably changed our world and discovery processes are veiled in mystery, which is why the thought processes underlying scientific thinking have attracted both scientists and nonscientists over the years (Tweney et al., 1981; Willingham, 2008). Scientific thinking is believed to be the key factor in developing the ability to use scientific knowledge in problem-solving (Norris & Philips, 2003; Showalter, 1974). Basically, problem-solving skills stemming from scientific thinking provide people with the ability to differentiate good and valuable information from meaningless data (Schmaltz et al., 2017). Unfortunately, not a lot has been done on advancing scientific thinking education in formal and nonformal settings in the US (Osborn, 2013). Moreover, adults like Master Gardener volunteers who actively participate in community outreach and gardening would benefit from learning about and applying scientific thinking because local gardeners often call upon them in the community to solve problems regarding plant growth, diseases and pests. However, Master Gardener volunteers are trained with practical skills in gardening without including scientific thinking training.

The researcher of this study used an inquiry-based learning approach to serve as a tool enabling scientific thinking. An inquiry-based learning approach provides learners with knowledge and skills needed to develop both evidence-based thinking and critical thinking (Facione, 2011). Those skills are dependent upon one another, and they fit into the greater picture of scientific thinking (Shargel & Twiss, 2019). Moreover, Nelson (1999) emphasized how humans' future will depend on how effectively they will incorporate science and technology in their decision-making and problem-solving routines in today's world where science and technology are prevalent in our lives. Therefore, incorporation of competencies for the 21st century in our lives is believed to become a driving force to success in people's personal and professional settings (Janoušková et al., 2021).

The Purdue Master Gardener program is a program that trains volunteers on technical skills about horticultural crops gardening and community needs. In return volunteers train the public on gardening or work in maintaining community gardens. They have mainly two types of trainings. The preliminary training to train new members and advanced trainings for active members to keep them up to date with new knowledge in gardening (Meyer, 2007). As gardening aligns with solving problems to maintain crops healthy, problem-solving skills for Master Gardener volunteers are crucial. One of the most efficient ways to develop problem-solving skills is the use of scientific thinking (Klahr et al., 2018). However, almost all the trainings Master Gardener volunteers receive focus on technical skill about growing and maintaining horticultural crops (Langellotto et al., 2015), but not scientific thinking process related to problem solving.

Before defining scientific thinking, it is worthy to note Kuhn's model (2010) and characterization of scientific thinking as a process that starts with recognizing one's existing understanding (theory), followed by intentions to recognize evidence as the means to advance this understanding. Kuhn (2010) continues by emphasizing that evidence should be interpreted distinct from one's existing understanding to successfully get implications of the evidence. Scientific thoughts are constituted by conceptual and procedural aspects; sometimes taken in isolation, and other times in interrelationship (Newton & Roberts, 2004; Zimmerman, 2000). Newton and Roberts (2004) and Zimmerman (2000) refer to these aspects as specific domain knowledge and general domain strategies, respectively. Domain-specific knowledge is characterized by the concepts that individuals develop about phenomena from the fields of natural sciences (Niaz, 1994). Multiplication in mathematics, and photosynthesis concepts are examples of this type of knowledge. General domain strategies, on the other hand, refer to reasoning and problem-solving strategies used in discovering and interpreting categorical or causal relationships (Niaz, 1994). Examples are the elaboration and testing of hypotheses, the evaluation of evidence, among others. As Klahr and Dunbar (1988) and Niaz (1994) asserted domain-general knowledge and domain-specific knowledge are inseparable. For the purpose of this study, scientific thinking consists of domain-specific knowledge and domain-general strategies that are interrelated through an inquiry-based project with Purdue Master Gardener volunteers.

1.2 Problem Statement

Scientific thinking is essential in developing the ability to think clearly and handle problems in an impartial way (Blair & Goodson, 1939). However, there is still a lack of adequate training of the general public to incorporate scientific thinking into their everyday life (Borchelt, 2001). In addition, limited research studies about scientific thinking have been conducted, especially among adults like Master Gardener volunteers who get involved in both personal gardening and community outreach. Although a few studies have found the effectiveness of inquiry-based learning approach in promoting scientific thinking, limited studies explored scientific thinking among adults after participating in inquiry-based projects. Hence, the purpose of this study was to qualitatively explore Purdue Master Gardener volunteers' scientific thinking throughout a home hydroponics inquiry-based project and to describe their experiences to complete the learning module.

1.3 Significance

The significance of this study is primarily defined by four reasons.

Firstly, its contribution to a knowledgeable society through informed decision making. Enhancing scientific thinking among the general public will impact societal well-being with citizens putting forward science-based decisions. Specifically, the findings of this study will inform stakeholders in non-formal education about the utility of scientific thinking in everyday life. This would contribute to shifting the focus on types of educational programs from programs emphasizing memorization to programs focusing on scientific thinking.

Secondly, this study will play a role in improving curriculum development by using inquiry-based learning approach in non-formal adult learning settings. Curricula developers and instructors would use the findings of this study to strengthen their education programs that incorporate scientific thinking as a form of problem-solving. That would continue to inform the general public to continue recognizing the role science plays in improving American's quality of life (Funk et al., 2015). Moreover, using scientific thinking in problem-solving aligns with competencies of 21st century needed to successfully combine content knowledge and critical thinking (Janoušková et al., 2021).

Thirdly, this study will mainly benefit the general public with scientific thinking skills instead of limiting those skills to a small portion of the population within the scientific community. As scientific thinking is "characterized by skepticism, objectivity, an appreciation of uncertainty and the flexibility to alter one's beliefs in the face of conclusive evidence" (Kabraji, 2004, p. 949), equipping Purdue Extension Master Gardener volunteers with scientific thinking skills would allow them to efficiently contribute to environmental protection practices like limitation of water run-offs and erosion prevention, increase healthy foods in their community, and train others on sustainable gardening during their community services activities.

Lastly, contribution to agricultural education development through Purdue Extension Master Gardeners program with an increased outreach to beneficiaries of the program. Extension Master Gardeners National Counsel (2020) estimated 84,700 Extension Master Gardener volunteers in the United States who volunteered 3.1 million hours estimated to contribute $88 million worth of time volunteering contributed to the general public. In 2021, Purdue Extension Master Gardener program reported 2,619 volunteers who contributed 134,591 volunteer hours estimated to be a $3.3 million contribution. Therefore, helping volunteers to increase efficiency in their volunteerism, would benefit the state and the country in general.

1.4 Purpose of the Study

The purpose of this study was to explore and describe Purdue Extension Master Gardener volunteers' scientific thinking, learning experience, and intentions to apply scientific thinking throughout and after a home hydroponics inquiry-based project. This learning project was designed to help participants practice their scientific thinking. This research was conducted using a qualitative research method approach.

1.5 Research Questions

The research focused on the following research questions:

1. How did Purdue Extension Master Gardener volunteers demonstrate their scientific thinking in the home hydroponics inquiry-based project?

2. What were Purdue Extension Master Gardener volunteers' learning experiences in utilizing the online module for learning about home hydroponics and inquiry?
3. How did participants intend to apply scientific thinking beyond the inquiry-based hydroponics project learning experience?

1.6 Assumptions

1. The research of this study used a deductive approach.
2. Post-positivistic research assumes that "social reality is out there and has enough stability and patterning to be known" (Bisel & Adame, 2017, p. 1).
3. The data collected from Purdue Extension Master Gardener volunteers accurately reflected their honest thoughts, perceptions, and experiences.
4. The participants will complete the online modules, and project activities.
5. Case study is effective as a unit of analysis to explore Purdue Extension Master Gardener volunteers' scientific thinking throughout the home hydroponics inquiry-based learning experience.
6. Participants had their own environment, and they were engaged in activities that involve thinking and reflecting on their own thoughts.

1.7 Limitations

1. Participants were self-regulated during their learning experience which might result in some to fall behind. The researcher put effort to monitor the participants' learning progress.

2. The researcher's role in developing the learning experience that were used in this study might have been led to pre-conceived assumptions.

3. The researcher was a Master of Science degree student and was not an expert in developing online module and in producing the instructional materials.

4. The researcher's personal interest in the participants' success in the program were controlled through the researcher's advisor reviews.

5. The results of this study are not generalizable because of the small sample size and the qualitative nature of the study.

1.8 Definitions

1. **Scientific thinking**: "Scientific thinking refers to both thinking about the content of science and the set of reasoning processes that permeate the field of science: induction, deduction, experimental design, causal reasoning, concept formation, hypothesis testing, and so" (Dunbar & Klahr, 2012, p. 611).

2. **Hydroponics**: is "a widely and frequently used technique for growing plants without soil, providing for a considerable degree of control of the elemental environment surrounding the root" (Benton, 1982, p. 1003).

3. **Master Gardener volunteers** are "recruited to assist Extension with the public dissemination of information and research related to consumer horticulture that is generated by land-grant university scientists. They answer questions, give presentations, do hands-on training, and many other educational activities" (Dorn et al., 2021, p. 1251).

4. **Inquiry-based learning** is a learning process whereby learners "direct their own investigative activity by completing all stages of scientific investigation such as formulating hypotheses, designing experiments to test them, collecting information, and drawing conclusions" (Keselman, 2003, p. 898).

   - **Open inquiry:** is a learner-centered learning approach in which learners bring forward a question to investigate, conduct an experiment, and communicate outcomes without a direct intervention of the instructor (Colburn, 2000).
   - **Guided Inquiry:** is a learner-centered approach in which the instructor helps learners develop an inquiry while learners play a bigger role throughout the process (Martin-Hansen, 2002).

5. **Andragogy:** is "the art and science of helping adults learn" **(**Knowles, 1980, p. 707).

6. **Case study research:** is "an empirical inquiry that investigates a contemporary phenomenon in depth and within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident" (Yin, 2009, p. 14).

CHAPTER 2. LITERATURE REVIEW

2.1 Overview

This chapter describes details about scientific thinking in adult education, which is the main focus being covered in this study. Scientific thinking skills will be described in the context of non-formal learning settings whereby four phases of scientific thinking will be explored. Also, adult learning pedagogy used during participants learning experience, as well as the conceptual framework that informed this study, will be discussed. Moreover, the word “theory” will be used to describe individual’s existing knowledge and understanding of a phenomenon (Kuhn, 2010).

2.2 Purpose of the Study

The purpose of this study was to explore and describe Purdue Extension Master Gardener volunteers’ scientific thinking, learning experience, and intentions to apply scientific thinking throughout and after a home hydroponics inquiry-based project. This learning project was designed to help participants practice their scientific thinking. This research was conducted using a qualitative research method approach.

2.3 Research Questions

The research focuses on the following research questions:

1. How did Purdue Extension Master Gardener volunteers demonstrate their scientific thinking in the inquiry-based hydroponics project?

2. What were Purdue Extension Master Gardener volunteers' learning experiences in utilizing the online module for learning about home hydroponics and inquiry?
3. How did participants intend to apply scientific thinking beyond the inquiry-based hydroponics project learning experience?

2.4 Literature Review Methodology

The literature search conducted in this study was informed by peer reviewed articles searched using Eric (EBSCO Interface) database, Google, Google Scholar, Journal of Research in Science Teaching, Elsevier, and Journal of Agricultural Education. The most common phrases used were: "Scientific thinking", "Inquiry-based learning", "Guided inquiry", "Evidence-based reasoning", "Scientific thinking + adult education", "non-formal education + adult learning".

2.5 Scientific Thinking

The phenomenon of interest was scientific thinking, which refers to "both thinking about the content of science and the set of reasoning processes that permeate the field of science: induction, deduction, experimental design, concept formation, and hypothesis testing" (Dunbar & Klahr, 2012, p. 611).

The reasoning processes referred to in the definition of scientific thinking above can be explained as follows:

The type of induction mentioned is a way of proposing items from the same classification whereby one item from the renowned classification is classified together with the other item from the same category (Gutwill & Allen, 2012; Kuhn et al., 1988). As Hayes et al., (2010) and Kuhn (2002) asserted, inductive reasoning is consistent with much of the reasoning that humans use in everyday decision making. Abduction is applicable in a situation whereby new experience or knowledge is made with interpretation of our observations or effect from causes (explanations) (Gutwill & Allen, 2012; Kuhn et al., 1988). For deduction thinking, these procedures are consistent to conditions in which a hypothesis is used to manipulate variables so that a conclusion can be made from the findings (Gutwill & Allen, 2012; Kuhn et al., 1988). Deductive thinking assertions include information or procedures that express an assumption about how the world operates, with a conclusion that originates from such assertions and assumptions (Dunbar & Klahr, 2012). Moreover, a deductive thinking leads to an experiment.

Individuals perform deductive reasoning by conducting experiments in which they design and interpret a scientific inquiry. Experiments help learners conduct systematic data-driven investigations (Schwichow, 2022). As a result, those experiment practices instill in learners' ability to differentiate valuable information from non-valuable data (Kuhn, 2005). Novak (1977) explained how learners come with intuitive view of the world which may not be the same as the scientific concept taught in the new learning experience. That is referred to as prior knowledge seen as a set of knowledge as well as the way that knowledge is arranged together and applied (Novak, 1977; Resnick, 1981). Therefore, learners may develop new concepts that would complement the already existing concepts throughout the learning process (Schwichow, 2022).

2.5.1 Scientific Thinking Development

Scientific thinking is not considered an inherent skill but instead develops progressively from childhood to adulthood in accordance with our adopted theories about the world (Kuhn, 2002). Kuhn (2002) characterized scientific thinking in four phases: "Inquiry, Analysis, Inference, and Argument" (p. 378). In addition, each phase is accomplished through doing three tasks as summarized in Table 2.1. However, the fourth phase of scientific thinking “argumentation” that mainly focuses on the debate about findings of the previous phases will not be discussed as this study will focus on the development of the first three phases of scientific thinking.

Table 1. Kuhn’s (2010) Three Phases of Scientific Thinking

	Inquiry	**Analysis**	**Inference**
Task 1	Formulate questions to ask of data	Seek and detect patterns	Acknowledge indeterminate claims
Task 2	Recognize its relevance to theory	Make comparisons	Reject unjustified claims
Task 3	Access data	Represent evidence [distinct from theory]	Draw justified claims

The “Inquiry” phase is the first and most important phase because it shapes the direction of subsequent phases, and it is at this phase where questions to be asked and goals to achieve are established. Also, the inquiry phase presents a central challenge of distinguishing findings of inquiry from theory one holds (Kuhn, 2002). Kuhn (2002) continued to explain that distinction does not necessarily have to weigh out pre-existing theories, instead the emphasis should be put on recognizing the independence of the information gathered from pre-existing theories. Therefore, based on how well the three tasks of inquiry phase are done, five outcomes are possible: “Generate outcomes, Generate best outcome, Examine variance in outcomes across instances, Find out what makes a difference in outcome, and Find out if X makes a difference in outcome” (p. 381). Those five outcomes range from the simplest form in which the learner picks an activity or asks the simplest form of a question that leads directly on “generating outcomes.” The advanced form of inquiry leading to exploring variables making the difference in a given process or those that help to predict the outcome.

The second phase "Analysis" is procedural in nature, and it is used in helping relate evidence to one's theory or used to reach the phase of inference, which is declarative in nature (Kuhn, 2010). Strategies used in this phase are classified in five levels: "Ignore evidence, Invent evidence to fit a theory, Interpret an instance as illustration of theory, Compare selected instances as support for a theory, and Choose for comparison two instances that allow test of a theory" (Kuhn, 2010, p. 382). This phase develops the ability to consider information processing before own judgment, contribute to taking necessary steps before jumping to conclusions, and put facts ahead of long-established opinions and believes (Elder & Paul, 2012).

The third phase of scientific thinking is "Inference" that aligns evidence and one's theory through five levels. The basic level is characterized by predominance of one's theories over the evidence while on the highest level evidences are interpreted separately from one's theory (Kuhn, 2002). Strategies used in this phase are classified in five levels as well: "Unrepresented, Represented without evidence, Represented as theory with illustrative evidence, Represented in relation to supportive evidence, Represented in relation to both consistent & inconsistent evidence" (Kuhn, 2010, p. 382). The main framework remains the consciousness of the learner to evaluate the basis of their statements and extend of their development beyond boundaries of traditional scientific subjects (Kuhn, 2002).

Researchers agree upon the process through which scientific thinking is performed and developed starting from asking a meaningful question or defining a problem, followed with gathering data, performing analysis and draw a conclusion that informs the learner irrespective of their preconceived reality or theories (Dunbar & Fugelsang, 2005; Kuhn, 2002; Paul & Elder, 2012; Schafersman, 1997). However, those researchers focused on scientific thinking development in youth, and a little attention was given to adults. For example, Dunbar and Fugelsang (2005) did a systematic review of literature focusing on students mainly middle school or younger explained scientific thinking as a process that starts with identifying a problem which leads to questioning different aspects of the problem, therefore, formulate a hypothesis. They continually suggested that hypothesis leads to search of evidence, and through analyzing evidence, a conclusion is made through inference. The conclusion made leads to supporting or casting doubt on one's hypothesis, and finally use that knowledge to solve the problem (Dunbar & Fugelsang, 2005). Schafersman (1997) on the other hand, outlined how scientific thinking can be pursued through either asking a meaningful scientific question or identifying a significant problem. Schafersman (1997) also supports generating a hypothesis and gathering and analyze data as means to answer the question or solve the problem and finally, make a conclusion out of findings.

Limited studies were found that focused on adult scientific thinking. Janoušková et al. (2021) who worked on scientific thinking among adults, made a framework pertinent to development of scientific thinking within service and manufacturing industries. In addition to the scientific thinking component agreed upon by prior researchers, Janoušková et al. (2021) added "knowledge of industry-specific skills" in addition to prior knowledge. Also, Schunn and Anderson (1999) studied scientific reasoning among adults focusing on domain general and domain specific skill. Participants in this study were psychologists teaching in college, college professor in other fields apart from psychology, and undergraduate students. The study found a significant difference in domain-general skills between experts (psychologists and non-psychologists) and undergraduate students whereby psychologists used many of domain-general skills than college students during their experiments. Therefore, Schunn and Anderson (1999) concluded that expertise in scientific reasoning covers both domain general and domain-specific skills.

Likewise, Klahr et al. (1993) conducted a study comparing college students trained in technical skills with 3rd and 6th graders. After teaching them about programmable robots, researchers gave them a new operation (task) with a hypothesis. They asked study participants to conduct an experiment leading to understanding how the new operation works. College students performed better than school students. As a result, researchers realized that college students have performed much better in implementing domain-general skills beyond the simple logic of the experiment compared to 3rd and 6th graders. Researchers, therefore, concluded that prior knowledge played a role in the performance of college students compared 3rd and 6th graders experiments.

2.6 Evidence-based Reasoning

Two scientific thinking phases (Kuhn, 2002), analysis and inference, particularly involve the process of evidence-based reasoning. Evidence-based reasoning is fundamental for many problem-solving and decision-making practices in a wide variety of domains, including biology, law, geography, medicine, and archaeology. (Murphy, 2003). What constitutes evidence? In its simplest sense, "Evidence may be defined as any factual datum which in some manner assists in drawing conclusions, either favorable or unfavorable, to some hypothesis whose proof or refutation is being attempted" (Murphy, 2003, p. 1). While evidence usually leads to conclusions, it is not always the case. Evidence-based reasoning can be complex, which may lead to probable conclusions (Boicu et al., 2011), mainly because evidence are either partial, imprecise, or inconclusive in the face of hypotheses (Schunn & Anderson, 1999).

Different approaches can be used to achieve evidence-based reasoning. In general, evidence-based reasoning, which is a set of scientific thinking process (Dunbar & Klahr, 2012), includes deductive, inductive, and abductive approaches (Boicu et al., 2011). Deductive, inductive, and abductive approaches serve different utilities in terms of conducting scientific thinking. Penner and Klahr (1996) assessed how deductive reasoning uses prediction to guide evidence gathering that in end leads to conclusion. Through an inquiry-based experiment, Penner and Klahr (1996) studied learners' ability to formulate, test, and make a conclusion about a hypothesis to determine whether an object will sink or float. They found that the preference of younger children (10 years old) is to perform domain-specific knowledge rather than domain-general knowledge. Based on how they formulated hypothesis and interpreted the results, younger children failed to integrate new knowledge from an experiment (Penner & Klahr, 1996). They either ignored outcomes on their experiments or choose materials they assumed would confirm their theory. On the other hand, older children (14 years old) reflected on their personal beliefs and experimental outcomes to interpret their experiments and making conclusions (Kenner & Klahr, 1996). As for inductive reasoning, researchers like Gelman (1988) explained that inductive inferences mainly are founded on the utilization of categories in which, facts or evidence found to be true in one category remain true also in other categories. An example would be "when children learned that a color TV has parts made out of quercous, they were most likely to generalize to another color TV" (Gelman, 1988, p. 85).

Overall, Kuhn (2002) explained how inductive and deductive reasoning complement each other in a way that inductive reasoning which vastly predominate in human thinking is characterized with the generalization based on the known information while deductive reasoning is characterized by applying deductive logic to make a conclusion out of information given.

2.7 Inquiry-based Teaching and Learning

In the field of education, ways have been identified to help learners develop and practice scientific thinking. Among the commonly used teaching methods, inquiry-based teaching has been documented to be one of the effective instructional designs that help learners develop and practice scientific thinking (Kuhn, 2010). Inquiry-based learning have also been found to enable learners develop conceptual understanding and critical thinking (Klahr, 2000; Yuksel, 2019). In this study, inquiry-based learning was chosen because it was used to help Purdue Extension Master Gardener volunteers to practice problem solving through their experiments.

Harlen (2013) defined inquiry as seeking information or meaning by asking questions or examining facts. Inquiry-based teaching and learning refers to the teaching practice centered on learners' experiences in which they actively participate by posing a question or defining a hypothesis, collecting and analyzing data as means of giving an explanation to a phenomenon (Caswell & LaBrie, 2017). Inquiry-based learning methods were found to be among the best strategies to engage learners in the knowledge process whereby a real-world problem or case study are used to help learners recognize the need of data and conceptual understanding (Avsec & Kocijancic, 2016; Martorell et al., 2009). Inquiry-based instruction fosters learners' critical thinking, the ability of using data to make conclusions or solve a problem, and communication capabilities (Hwang & Chang, 2011; Minner & Century, 2010). Harlen (2013) mentions that developing understanding through learners' own thinking and reasoning has many benefits for learners including: enjoyment and satisfaction in finding out for themselves something that they want to know, seeing for themselves what works rather than just being told, satisfying and at the same time stimulating curiosity about the world around them, and developing progressively more powerful ideas about the world around them.

Instructional design used inquiry-based learning results from the most part out of the work of Jean Piaget (1972), John Dewey (1997), and Jerome Bruner (1961). Therefore, such work is found into the philosophy of constructivist learning theory (Cakir, 2008). John Dewey's work focused on applications of constructivism theory in inquiry-based learning in which learners build upon their prior knowledge to engage in inquiry as a tool to practice reflection in problem-solving (Dewey, 1923; Santrock, 2017). Jerome Bruner (1961), another constructivist advocated that learning should actively involve learners into the whole learning experience by creating an environment for active learners instead of passively assimilate information (Ackermann, 2001; Roblyer & Doering, 2013). Jean Piaget's work focused on how learners best learn with schemas and stated that learning best occurs by interpreting new learning experiences based on what the learner already knows (Piaget, 1978). As Shrager and Siegler (1998) and Siegler (1991) pointed out that when learners, who don't have a higher level of prior knowledge, try to generate correct procedures, they face more challenges than those with higher prior knowledge. As a result, learners with higher levels of prior knowledge perform better on setting up procedures leading to correct information. Therefore, learners increase their knowledge and strengthen their abilities to conduct an inquiry.

The ultimate goal of inquiry-based learning is to instill in learners' ability to "formulate good questions, identify and collect appropriate evidence, present results systematically, analyze and interpret results, formulate conclusions, and evaluate the worth and importance of those conclusions" (Lee et al., 2004, p. 9). To achieve that, different models were developed to characterize inquiry-based learning (Pedaste et al., 2015). Bybee et al. (2006) described the 5E learning cycle model lists five inquiry phases: Engagement, Exploration, Explanation, Elaboration, and Evaluation. On the other hand, White and Frederiksen (1998) named other five phases of inquiry cycle as: Question, Predict, Experiment, Model, and Apply. Both approaches differ in a way that the former approach uses inductive approach by exploring the phenomena of interest while the latter uses a deductive approach of inquiry (Pedaste et al., 2015).

2.8 Theoretical Framework

Adult learning pedagogy (andragogy) informed the design and development of the learning experience in this study. Andragogy has been key in generating meaningful experiences to learners through setting up boundaries with regard to learning experiences while providing adequate information and appropriate environment.

2.8.1 Adult Learning Pedagogy (Andragogy)

The essential meaning of the concept of andragogy has to do with adults. The Greek, aner (genitive andros), means "man", while agein means "to lead"; so, andragogy means "leading men," which can be paraphrased as "leading adults" (Mohring, 1990). Principles of andragogy that guided the learning experience during this study, have a foundation to the effective learning experience of adults that mirrored constructivism learning theory. Knowles's model of andragogy (1980), believed to be the foundation of adult education, is based on six assumptions of how adult education occurs as follow:

1. Independence and self-direction are two qualities that guide a person as they get older. Therefore, the instructor serves the role of a facilitator during the learning process.
2. Adults use their prior experience during learning.
3. Their readiness to learn becomes oriented increasingly towards the developmental tasks of their social roles.
4. Adults learn better with a real-world or problem-centered instructions (Knowles, 1990).
5. Intrinsic factors prevail to extrinsic factors for adult learners (Knowles, 1984).
6. Adults need to know the reason pushing them to learn what they are going to learn (Knowles, 1980).

As people mature, their educational background and life experiences tend to become more complex due to multifaceted factors that they must handle in order to succeed in life (Wlodkowski, 2008). Therefore, their learning needs change from being taught all they need to know as kids to a self-directed with a facilitator to oversee the learning process (Chesbro & Davis, 2002). In this study, this was achieved through designing an inquiry-based asynchronous learning module that aligns with participants' everyday life activities. As a result, participants had flexibility in deciding appropriate time to study, they had prior knowledge build-on while learning, they had the opportunity to practice learning in a real-world setting, and the eagerness to improve their gardening practices guided their intrinsic motivation.

2.9 Conceptual Framework

A conceptual framework that was used in this study illustrates how inquiry-based learning experiences were used to guide Purdue Extension Master Gardeners volunteers in exhibiting scientific thinking skills (Figure 1).

The online module learning experience, which is on the far-left hand side of the Figure 1, was followed by a guided inquiry instruction in which participants conducted an experiment to foster scientific thinking skills (Stander et al., 2018). Learners used hydroponics as a context to develop an inquiry and they were provided with worksheets (Appendix C) to use in data collection. Moreover, participants were shown a typical experiment to follow while developing their own experiments.

Scientific thinking in this study was defined as to "both thinking about the content of science and the set of reasoning processes that permeate the field of science: induction, deduction, experimental design, concept formation, and hypothesis testing" (Dunbar & Klahr, 2012, p. 611).

The conceptual framework (Figure 1) showed that scientific thinking involves three components, prior knowledge, scientific methods, and reasoning processes (deductive, inductive, and abductive approaches). One of the principles of andragogy states that adults need to know the reason why they should learn something before learning it (Knowles, 1990). Participants' prior knowledge and the need for efficiency of problem-solving in gardening drove the inquiry to promote scientific thinking among participants. Scientific methods, posing a question or defining a hypothesis, and collecting and analyzing data as means of giving an explanation to a phenomenon (Caswell & LaBrie, 2017), are essential steps in the inquiry-based instruction that helps learners develop scientific skills, as well as practice scientific reasoning to make an evidence-based conclusion through inductive, deductive, and/or abductive reasoning processes.

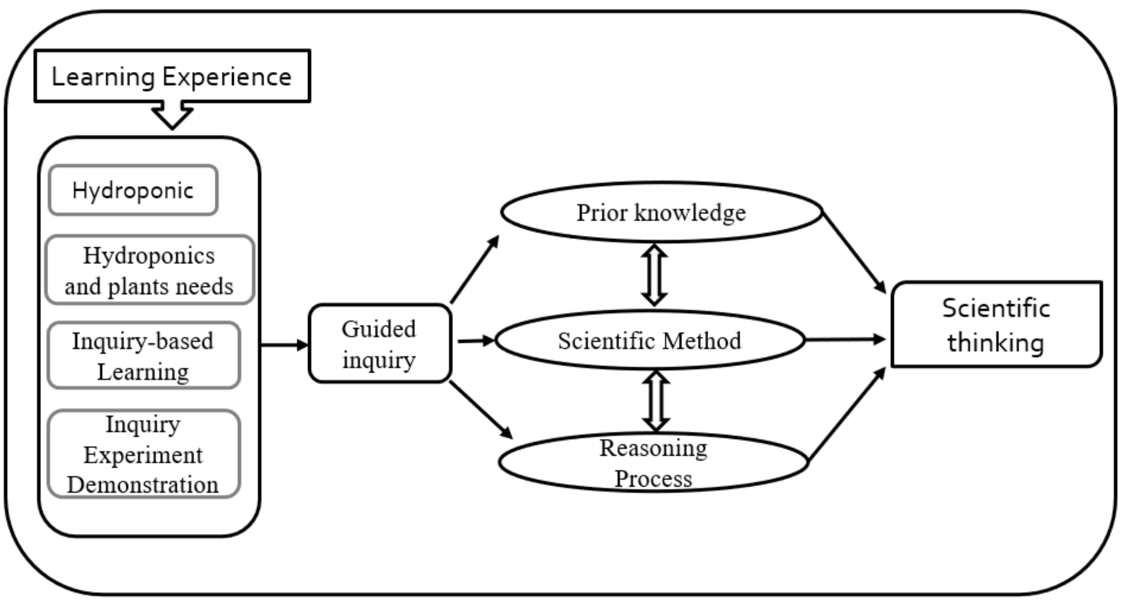

Figure 1. Conceptual Framework

2.10 Master Gardener Volunteers

The Master Gardener concept was started by Dr. David Gibby in 1972 in Washington State (Meyer, 2007). The main idea was to support his initiatives in extension work teaching horticultural practices to the general public (Boe et al., 1997). There is no nationwide Master Gardener office, only state or county coordinators, which leads to slightly different approaches from different states (Meyer, 2007). Some states focus on increasing the number of Master Gardener volunteers with the aim to expanding horticultural practices knowledge in the public, whereby others focus on one small group of volunteers (Stouse & Marr, 1992).

Mainly, Master Gardener volunteers join the program with the intent to learn more about horticultural knowledge (Boyer et al., 2002), while other reasons to join Master Gardener program are to contribute to the community development (Kirsch & VanDerZanden, 2002); educating the general public good practices for environmental protection, and indirectly contribute the economic development at the local, state and national level (Rohs & Westerfield, 1996).

Master Gardener activities evolved from mainly answering phone calls (helping consumers in home gardening) to the active role of practicing gardening and engaging with the general public, mainly local community, with sustainable horticultural practices (Meyer, 2007). The program progress appears in different perspectives as it evolved to the extent that now Master Gardener volunteers can make pesticides recommendations and handle most horticultural extension consumers needs as it would be done by Extension agents (Sciarapa et al., 2004). Master Gardener volunteers sometimes create and manage public gardens as an example to demonstrate new crop varieties adaptable to the local climate conditions (Meyer, 2007). Teaching how to maintain gardens is one of the main roles that Master Gardener volunteers play as educators. Some programs have engaged Master Gardener volunteers in projects that are not typical Extension programs, such as planting and maintenance of public gardens or data collection for research projects (Meyer, 2007).

The Master Gardener Program in Indiana is operated through Purdue University, a Land-Grant university located in West Lafayette, Indiana. Like other Master Gardener programs, Master Gardener volunteers are recruited and trained through Purdue University and the county Extension offices throughout the state. New volunteers undergo a series of trainings on different horticultural subjects ranging from growing crops, and pests and diseases control technics, to post-harvest handling and environmentally friendly practices. They are mainly females, often holding a college or higher degrees with some to no experience in farming (Rohs et al., 2002).

Master Gardener volunteers were chosen to be participants in this study because of their background in horticulture field and their potential impact to the community. Because scientific 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), it will help participants and Master Gardener beneficiaries in becoming informed consumers, citizens, and future professionals who would be able to solve complex problems in society.

2.11 Need for the Study

This study addressed the gap in the literature regarding the need for a study to qualitatively explore adults' scientific thinking in non-formal education settings. Exploring scientific thinking contributes to bridging the gap between enthusiasm of scientific community's fast progresses in science and a different trend of the general public becoming interested in learning about or supporting science (Funk et al., 2015). However, limited studies about scientific thinking have been conducted, and few of studies were found about scientific thinking among adults in non-formal education settings. Other literature found was limited to formal education settings, mainly in K-12 settings (Dunbar & Fugelsang, 2004; Murtonen & Balloo, 2019; Schafersman, 1997) and college settings (Dunbar, 1993; Kuhn, 1991; Qin & Simon, 1990).

In terms of participants, Master Gardener volunteers are predominantly lifelong learners about gardening and many of them contribute to their community through community service activities related to gardening. They are trained on technical skills about horticultural crops gardening and community needs (Boyer et al., 2002; Dorn et al., 2019). Moreover, people are attracted to join the Master Gardener program with the aspiration to learn more about horticulture and serve the community (Boyer et al., 2002; Schrock et al., 2000). However, limited studies were available that focused on Master Gardener volunteers' learning of content knowledge (Rohs et al., 2002), as well as their recruitment and retention (Dorn et al., 2018). The lack of literature about scientific thinking among Master Gardeners volunteers suggests the need to explore more into this field. Moreover, it is important to promote scientific thinking among adults so that individuals can make decisions based on reasoning pertaining with such thinking.

CHAPTER 3. METHODS

3.1 Overview

This section explains the research methods used to conduct this study. The researcher detailed the approach that was used, described study participants, participants' inquiry-based learning project, data collection and data analysis process as well as researcher's positionality and trustworthiness as related to this study.

3.1.1 Purpose of the study

The purpose of this study was to explore and describe Purdue Extension Master Gardener volunteers' scientific thinking, learning experience, and intentions to apply scientific thinking throughout and after a home hydroponics inquiry-based project. This learning project was designed to help participants practice their scientific thinking. This research was conducted using a qualitative research method approach.

3.1.2 Research Questions

The research focuses on the following research questions:

1. How did Purdue Extension Master Gardener volunteers demonstrate their scientific thinking in the inquiry-based hydroponics project?
2. What were Purdue Extension Master Gardener volunteers' learning experiences in utilizing the online module for learning about home hydroponics and inquiry?
3. How did participants intend to apply scientific thinking beyond the inquiry-based hydroponics project learning experience?

3.1.3 Research Methodology

The researcher used a qualitative research method because he wanted to explore participants' experiences and interpretation of their experiences throughout the participation in an inquiry-based learning project (Merriam & Tisdell, 2016). Empirical qualitative data collected in this study were obtained through interviews, notecards, and worksheets, which were then condensed, coded, whereby categories and themes were created to inform interpretation (Saldaña, 2016). This qualitative study used a multiple case study approach because of the bounded nature of the phenomenon, limited number of participants, and defined timeframe (Merriam & Tisdell, 2016).

Gerring (2007) characterized case study research methods with different meanings mainly tied to (1) the use of small sample size with a qualitative research method, (2) in-depth analysis with a wide-range investigation of a phenomenon, (3) high flexibility in data type, mainly non-parametric data, (4) the data collection method gathers real-world evidences that are directly linked to the research context, (5) the diffusion of the topic, as people can't easily distinguish the case from the context, (6) the use of several sources of data in a practice known as "triangulation" (e.g., complementary pieces of evidence gathered from interviews, worksheets, and notes from participants), (7) the study mainly focuses on one case at a time, (8) and investigating one phenomenon at a time, which are mainly what characterized this study. This study used this approach to explore Purdue Extension Master Gardener volunteers' experiences (Maxwell, 2013) and gain an insight into their scientific thinking skills after participating in an inquiry-based hydroponics project.

Multiple case study approach was chosen because it fits the context of exploring participants' scientific thinking skills as they exhibit such skills unique to each individual (Denzin & Lincoln, 2011). Moreover, a multiple case study approach also was used because the phenomenon of interest was interpreted in bounded group with a limited number of participants which permitted an insightful understanding and description of the phenomenon within the case (Merriam & Tisdell, 2016). Therefore, the multiple case study approach was based upon developing a profound analysis (Miller & Salkind, 2002) by exploring scientific thinking skills exhibited by Indiana Master Gardener volunteers after participating in an inquiry-based home hydroponics program.

3.2 Positionality

Positionality in research refers to the researcher's individual worldview and the way the researcher embraces research interpretations of the data and context (Rowe, 2014). It is interpreted in the lens of the researcher background that shapes both their beliefs and assumptions about the nature of the study and the phenomenon of interest (Ormston et al., 2014), and that positionality is reflected in the position the researcher takes in a particular study (Savin-Baden & Major, 2013).
A postpositivist researchers utilizes different instruments to explore more clearly a phenomenon and it mainly believes that there is no universal truth (Panhwar et al., 2017). The main objective of post-positivists is to study the phenomenon of interest as much as possible (Guba & Lincoln, 1994; Panhwar et al., 2017; Wildemuth, 1993). Post positivists utilize multiple dimensions to properly analyze and understand proper directions of any research study (Guba 1990; Fischer, 1998). The researcher's postpositivist paradigm influenced both the choice of the researcher's research topic and method used in this study exploring the scientific thinking among Purdue Extension Master Gardener volunteers. Through exploring the literature, the researcher found qualitative research methodology to be a good fit for exploring the phenomenon of interest because he wanted participants to share their perspectives and experiences using their own words.

Qualitative research methodology was a good fit because it provided an opportunity for an in-depth exploration of the phenomenon.

Assumptions of post positivism that guided the researcher are first evidence found in research are never perfect, but they are instead subject to being fallible (Ryan, 2006). As a result, absolute truth would never be determined. Second, research main goal is to analyze evidence and make a claim (Ryan, 2006). Moreover, during that period of making claim, researchers only keep most warranted claims (Ryan, 2006). Finally, information collected by the researcher are the only tools that should be used to shape the knowledge.

3.3 Partners and Recruitment Process

With the support from Purdue faculty and staff, the researcher and the Purdue faculty co-conducted a need assessment survey to explore non-formal/informal educator's knowledge and perspective of using hydroponics. The needs assessment survey was conducted with 166 non-formal/informal educators. Results of this study indicate that 81% of the participants identified themselves as home growers, and 92.6% acknowledged that they have heard about hydroponics before. However, 92% of the participants identified themselves as having very limited knowledge about hydroponics, while 95% mentioned that using hydroponics to grow food indoors can be a great educational activity to do with both youth and adults. The results of the needs assessment survey helped the researcher see the needs to provide hydroponics trainings to non-formal/informal educators, such as Master Gardener volunteers. The results also inspired the researcher to conduct a research study to explore Master Gardener volunteers' learning experience as adult learners. No data from the needs assessment survey were used during the analysis process of this study.

Master Gardener volunteers were selected because they were non-formal/informal educators. Master Gardener volunteers potentially could teach hydroponics to public. Additionally, Master Gardeners' prior knowledge and interests in gardening are important pre-requirements to the study, as prior knowledge was identified as one of the key components to conduct scientific reasoning. Through the Purdue Master Gardener program administration, the researcher recruited participants by sending them a recruitment letter (IRB-2021-1571) in December 2021 and the invitation was limited to Purdue Master Gardener volunteers. The recruitment criteria were based on participants who responded the invitation first and whither if they have prior knowledge and/or experience about hydroponics. The assumption was that early adaptors of Master Gardener volunteers have higher motivation toward to the project, and different professional expertise with hydroponic experiences have influence on how people interpretive their learning experience. The exclusion criterion was the Purdue Master Gardener volunteers who have less than one year's volunteer experience in the program and no prior knowledge and/or experience about hydroponics. Eight participants were initially recruited for the study. Yet, only four participants, who had previous hydroponics experience and had been volunteering Master Gardener more than one year, met the selection criteria (Table 2).

After selecting the potential participants, they were asked to sign a consent form. Only the participants who had signed the consent form were recruited to participate in the study. Four participants, all Indiana residents, were recruited. Three were female and one was male. Their Master Gardener volunteers experience range from 3 to 12 years (Table 2).

Table 2. Study Participants' Demographic

Pseudo name	Years of volunteering	Education level	Field of education	Sex
Bella	12	Associate Degree	Graphic Design	Female
Ruby	3	Master's Degree	Curriculum & Instruction	Female
Leo	8	Bachelor's Degree	Business	Male
Hope	4	High School	High School	Female

3.4 Learning Experience (Online Module)

This study used an online module that focused on inquiry-based learning through a home hydroponics system. The total learning experience, which also is the intervention, was about 10 weeks. Key components that facilitated the learning includes four lessons, which are (1) Introduction and background of hydroponics system; (2) How hydroponics meets the plant needs; (3) Basics about guided inquiry, and (4) A visual presentation (doing an inquiry activity with hydroponics), and a guided inquiry experiment. All learning materials were delivered through Google Classroom platform and participants were expected to spend about 20 minutes on each lesson. The lessons were asynchronous learning experience that instructed through voiced slide shows converted into a video. Each lesson had a deadline so that participants can provide and get feedbacks through 3-2-1 Notecards (Appendix F). The Notecard is a worksheet that participants used to share three things that they learned, two things that they found interesting, and one question they might have. The 3-2-1 Notecard helped learners reflect on their learning experience and allow learners to express their perceptions and interpretations toward the experience (Fosnot & Perry, 2005), which are part of scientific thinking process.

The first lesson focuses on hydroponics system definitions, and types and historical background. It also details environmental, health and financial benefits of using a homemade hydroponics system. The second lesson focuses on what plants need to grow, how plants acquire nutrients and how a hydroponics system is designed to fulfill those needs. The third lesson is a guided inquiry comprised of what “scientific inquiry” means, and its role. Learners are taught guided inquiry steps while they are taught how to use data in decision making. The last lesson is practical guidance by visually showing learners how to conduct a scientific inquiry experiment through the application of skills learned in prior lessons.

After the online learning experience, participants then performed a guided inquiry experiment, growing lettuce, as a way to apply skills learned. After finishing the online module, learners designed an experiment using the home hydroponics system that were provided to them. Each participant received two hydroponics kits to use in their experiment. All kit’s dimensions were 16.73 x 8.07 x 6.42 inches each and they came with water air pump and adjustable light. Even if they had opportunity to choose the topic of their interest, the researcher expected that participants who were going to demonstrate scientific thinking using a deductive reasoning, were going to use those kits to set up a comparative study. The comparative study was supposed to use one kit as a control and other kit as an alternative during the experiment. Below are pictures of the kits.

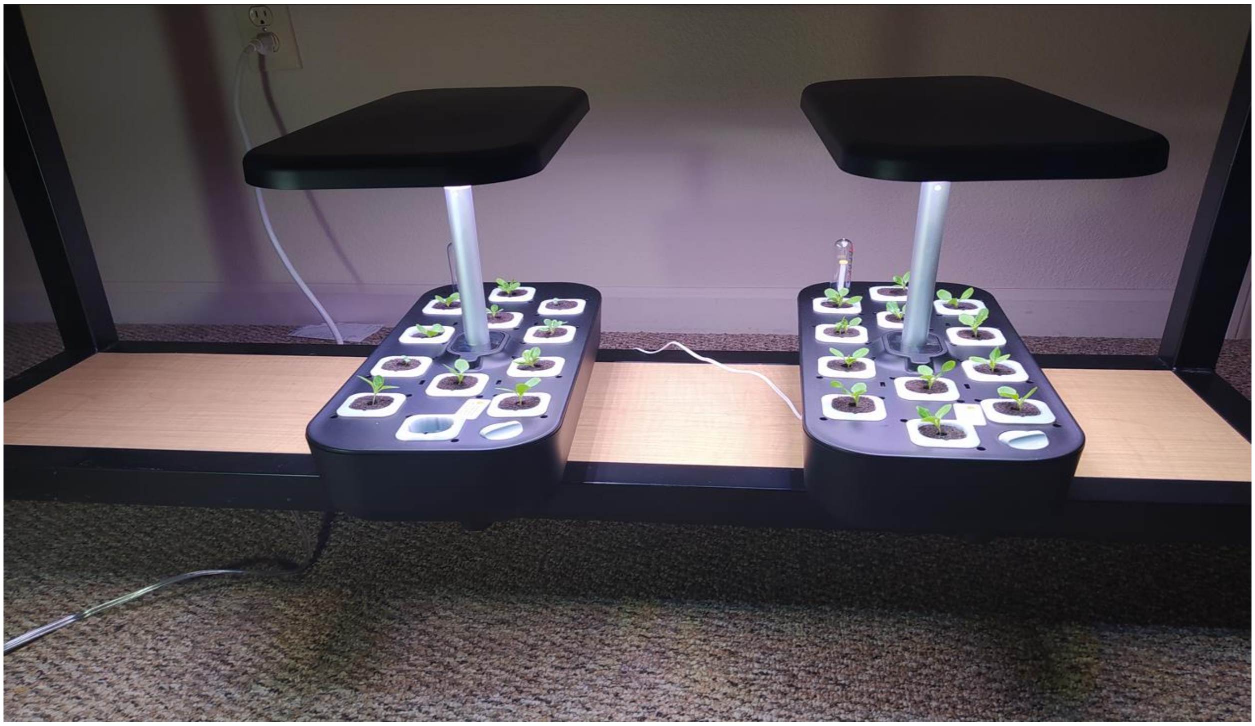

Figure 2. Hydroponics Kits used for experiments

During the guided inquiry process, participants collected data once a week on the pre-designed form and submit them on the Google Classroom platform. Participants collected data from the beginning to the end of their experiment. Data collected included planting date, lighting, amount and frequency of fertilizer application, leaf color and length based on their research interests using a provided template (Appendix C). Finally, during the implementation of the guided inquiry, participants implicated components of scientific thinking, which is to think about science content and the set of reasoning practices that pervade the field of science, in general. Participants' experiment timing and hypotheses can be found in Table 3.

Table 3. The Participants' Guided Inquiry Experiment and Hypotheses

Pseudo name	Start Date	End Date	Hypothesis
Bella	Jan 2022	March 2022	Distilled water will yield different results from basic water treated with acid
Ruby	Jan 2022	March 2022	Intensity of light will affect the growth of the plant
Leo	Jan 2022	March 2022	There is a difference in growth between distilled water and mineral water
Hope	Jan 2022	March 2022	Lettuce will grow faster in reverse osmosis water over hard water

3.5 Data Sources and Data Collection Methods

Multiple data sources were collected for the qualitative studies (Merriam & Tisdell, 2016; Robson, 2016). The data collected during this study were from three sources: (1) audio recordings from interviews (pre- and post-interviews), (2) formative assessment tool in the form of 3-2-1 Notecards, and (3) worksheets participants used during their guided inquiry experiment.

3.5.1 Interview

The pre-interview was about 30 minutes, and it was a semi-structured interview (see Appendix B). The pre-interview focused on participants' backgrounds in gardening, as well as their experiences with inquiry and problem-solving approaches regarding their gardening experiences. The participants participated in the first interview, which were conducted virtually via Zoom platform in December 2021. The first interview was conducted before the participants started learning using the online module. The purpose of pre-interview was to build a relationship with the participants and set up a baseline about their knowledge in gardening and hydroponics, inquiry and its application. Specifically, the pre-interview served as an attempt to explore the participants' ability to apply inductive, deductive and/or abductive reasoning in everyday life. Examples of questions asked in the pre-interview were: "What do you mainly do (in Master Gardener program) apart from learning?" or "How would you define a hypothesis in your own words?" or "How do you proceed when attempting to solve a problem in your garden?"

The post-interview was about 30 minutes, and it was semi-structured interview, which took place in March 2022 (see Appendix B). The purpose of the post-interview focused on the participants' experiences during the learning process, their perceptions of the module structure and content, as well as their interpretation and implication of the experiment they conducted. The post-interview also served as an attempt to explore the participants' ability to apply inductive, deductive and/or abductive reasoning after they conducted a scientific experiment.

3.5.2 3-2-1 Notecards

The second data source was generated using a formative assessment tool in the form of 3-2-1 Notecards that the participants filled out at the end of each lesson (see Appendix F). The 3-2-1 Notecards method is a form in which participants share three things they had learned, two things that were interesting in the lesson and one question they might have, as a mean of formative assessment and data collection technique. The notecards aimed to acquire information about participants' content knowledge gained during the learning process, learning experience regarding the module structure, and questions they had through their learning experience.

3.5.3 Worksheet

The third data source was generated using a worksheet that participants used during their experiment while growing lettuce. A pre-made worksheet (Appendix C) shared with participants included a space to share the hypothesis and variables, a table for data recording, and a space to write conclusions. Participants documented their experiment from the time they defined the hypothesis until making a conclusion about their experiment, which the worksheet could show their thinking process throughout the scientific experiment. The researcher used the worksheet to explore participants ability to collect data and make conclusion out of the data collected.

3.6 Data Analyses

To analyze each of the data sources, the researcher coded the different sources of data by referring to the framework developed (Figure 1). Then, the researcher interpreted themes that emerged. Scientific thinking was analyzed following three components identified in the conceptual framework (Figure 1, section 2.9), which are: prior knowledge, scientific methods, and reasoning process. The analysis focused on exploring the ability of individuals to use prior knowledge to formulate a hypothesis, get the data to test one's hypothesis, and coordinate evidence to make a conclusion (Dunbar & Klahr, 2012, Klahr et al., 1993, Kuhn, 2010), as well as their overall learning experience. Principles of andragogy (adult learning theory assumptions) were used to analyze participants' learning experience. Table 4 summarized data source as well as coding strategies used during the data analysis process. Strategies used by the researcher in data analysis were informed by the assumptions of a postpositivist paradigm.

3.6.1 Coding

To arrive to an in-depth analysis of scientific thinking among Purdue Master Gardener volunteers, two coding process was used and focused on identifying themes that emerged from codes to inform the researcher in interpreting the research findings (Saldaña, 2016).

Descriptive and pattern coding were used to analyze the data (Saldaña, 2016). A descriptive coding is a direct coding method whereby descriptive labels are assigned to data to offer a record of their topics. Descriptive coding summarizes sentences in a small structure like a single or two words to cover the basic topic of a piece of data collected (Saldaña, 2016). In descriptive coding, codes identify the topic not the content. As Tesch (1990) stated that descriptive coding focuses on "topic being that which is being talked about, whereas content is the actual substance of the passage" (Tesch, 1990, p. 119). On the other hand, pattern coding was used in the second coding cycle to group codes generated during the first coding cycle into themes, categories or concepts (Saldaña, 2016). Mainly, pattern coding played a role of a creating a more descriptive, yet specific unit of analysis out of the codes generated from the first coding cycle (Punch, 2014). Miles et al. (2014) described outcomes of pattern coding as "more meaningful and parsimonious units of analysis" (p. 86). Table 4 showed different data sources that were used to ensure triangulation and coding procedures.

Table 4. Data Analysis Procedure

Research Question	Data Source	Coding Procedures
RQ 1: Scientific thinking experiences in the project	Interview, Worksheet	Descriptive coding, Pattern coding
RQ 2: Learning experiences with online module	Interview, Notecards	Descriptive coding, Pattern coding
RQ 3: Intent to apply scientific thinking	Interview, Worksheet	Descriptive coding, Pattern coding

There were two coding cycles methods used during the data analysis process. The researcher used descriptive coding as a first coding cycle to group or summarize data that led the researcher to second coding cycle method (pattern coding). Pattern coding was used to group codes into other small number of categories in the form of themes (Saldaña, 2016). For the first and third research questions, the data sources were interview transcripts and interviewees' experiment worksheets, while for the second research question, the data sources used for this research question analysis were interview transcripts and notecards. The researcher used two coding cycles for all research questions.

The first coding cycle for the first and third research questions started by coding with interview transcripts followed by interviewees' experiment worksheets. For the second research question, the researcher used interview transcripts and notecards as data sources. After generating the codebook, the researcher triangulated the data. The researcher used descriptive coding to help him identify and summarize comparable contents of qualitative data in the first coding cycle (Saldaña, 2016). The second coding cycle was done using pattern coding to organize the codes from descriptive coding into themes (Saldaña, 2016). All codes generated from the first coding cycle were grouped according to their meaning and themes were created accordingly. In addition, the researcher interpreted the findings as a whole with a detailed and in-depth description of the cases. Table 5 below illustrates a coding process examples.

Table 5. Example of Coding Process

Themes	Codes	Quotes
Pattern coding	Descriptive coding	
Prior knowledge	Gardening skills	“Well, I've always been a gardener and have enjoyed it. I wanted to know better how to do it. To me, part of the fascinating part of gardening is trying new techniques”. Bella “Well, I can say that I successfully grow vegetables now and I kind of know how to start things from seed where I didn't know before”. Ruby “My personal gardening experience, it's always a learning process and has been since the beginning. I gardened with grandma and grandpa. And then about 35 years ago, I got back into it again, dug up a space and planted the garden, basically knowing what I knew at the time. And I had mixed success, but as I got interested in, I looked at more ways to grow things better and try things that I had never grown before. I'm to the point now, I usually try something new every year”. Leo
	Hydroponics	“And of course we already have two little hydroponic units”. Bella “And then I have taught hydroponics at a community outreach program”. Hope “So, the one part that pushed me the most was the fact that I had invested $200 in a (hydroponics) kit from Williams and Sonoma… And actually, what I found out was that the lights weren't adjustable, so they were fairly high from the plant … and our herbs came out, but they were kind of lanky and weak”. Ruby
Motivation	Community outreach	“I wanted to help my community….And I also work in a community garden where we grew 990 pounds of food and donated it to a food bank this year”. Hope

Reasoning process	Inductive reasoning	“I know we'd mentioned distilled water. We talked about the pH varying and the distilled water a little bit from batch to batch. But I think the thought was, "If mineral water has more things in it... " So my thought was, I know that in soil-based gardens, the type and quality of the soil, affect the amount of available nutrients to the plant. Clay-based soils has significantly less available nutrients. So I kind of wondered, does water do the same thing”? Leo “Sometimes I just have to say, "Well, I guess this is going to be a bad crop this year." Because fruit trees, you can't control a lot of things. And so some years are just bad. If we have an early frost, I have a bad crop”. Hope
	Deductive reasoning	“I guess one of my experiments might be to see if there's a difference between growing hydroponically or starting things hydroponically versus in soil, and if you get two seedlings that are the same heights with the same amount of light, one hydroponic and the other in soil, and you take them out and measure the length of their root system... My hypothesis would be that the length of the root system for the hydroponics would be longer”. Ruby “And so by having it controlled, I was able to actually tell if the water was making a difference or not. Where if I'm just talking with my colleagues and they tell me this worked for me, but they didn't do it in a controlled environment, you can't really tell why it worked for them”. Hope
Analysis	Compare findings	“So, out of bed A, I got just over half a pound, 0.51. And out of the second bed, which actually had filled out a little more with seven plants, I know, I believe... It's in my data. I believe it was about 0.47. So anyway, I calculated the yield per plant, and really, there was only a difference of about 3% in the two beds. To me, that's statistically not significant”. Leo “I measured how long the average leaf... I measured like three or four leaves and kind of got an average of how long it was. it was obvious that the one with the distilled water was over 5 inches long”. Bella

3.7 Trustworthiness

There are different attempts made to evaluate trustworthiness within qualitative research (Emden et al., 2001; Lincoln & Guba, 1985; Schreier, 2012). However, the widely used trustworthiness' criteria are those proposed by Lincoln and Guba (1985), which are credibility, conformability, dependability, and transferability. Such criteria were established to explain how effective the researcher conducted the study on the subject matter at every stage of the study (Lewis & Ritchie, 2003; Mason, 2002).

The credibility criteria were met through the use of triangulation. Triangulation refers to the process of using multiple data source to give a clear explanation of the phenomenon of interest (Stake, 2003). The data were collected from three different sources that included interview, notecards, and experiment worksheets. All three data sources were coded together, however, interview transcripts served as the major data source. The researcher used those three data sources to ensure that the phenomenon of interest is viewed and analyzed in different, but complementary ways.

The criteria of confirmability were also met through the use of triangulation as it mainly focuses on the accuracy in finding interpretation. It also limits the researcher biases in data interpretation (Lincoln & Guba, 1985). In addition, input from the advisory committee members were used to ensure the accuracy and practicability of materials used. Also, the researcher's positionality was discussed to clarify assumptions that guided the researcher worldview throughout this study (Merriam & Tisdell, 2016).

Dependability was achieved by thick description of the whole process that included the methods used in data collection as well as data analysis process. This allows the reader to understand details pertaining to this study's context which can be make it easier to adopt it or relate it to different contexts. In addition, coding procedure was supervised by Purdue University faculty experienced in qualitative research. The researcher and Purdue faculty performed an intercoder reliability, and any discrepancy that arose was resolved to reach the common understanding of the data. Therefore, it fulfills the transferability criteria as well. For example, the researcher and Purdue University faculty coded the first participant separately. They met and discussed the codes and themes that emerged. They then discussed and resolved discrepancies that were identified. After discussion, they also coded the second participant separately, met to discuss and resolve discrepancies that were identified. After achieving the coder reliability, the researcher coded the third and fourth participants independently.

CHAPTER 4. FINDINGS

4.1 Overview

This chapter describes the findings of the study. The findings from each of the four cases, Ruby, Leo, Bella, and Hope, are described through six categories, prior knowledge and problem-solving experience, motivation and value, scientific method, scientific reasoning, inquiry-based learning experience through the program, and intent to apply scientific thinking beyond the learning experience. In addition to single cases, cross-case analysis was also conducted to compare and contrast the findings for all four cases. The results from cross-case analysis were presented at the end of this Chapter 4.

4.2 Purpose of the Study

The purpose of this study was to explore and describe Purdue Extension Master Gardener volunteers' scientific thinking, learning experience, and intentions to apply scientific thinking throughout a home hydroponics inquiry-based project. This learning project was designed to help participants practice their scientific thinking. This research was conducted using a qualitative research method approach.

4.3 Research Questions

The research focused on the following research questions:

1. How did Purdue Extension Master Gardener volunteers demonstrate their scientific thinking in the inquiry-based hydroponics project?
2. What were Purdue Extension Master Gardener volunteers' learning experiences in utilizing the online module for learning about home hydroponics and inquiry?

3. How did participants intend to apply scientific thinking beyond the inquiry-based hydroponics project learning experience?

4.4 Findings for Ruby

4.4.1 Prior Knowledge and Problem-Solving Experience

Ruby has been a Master Gardener volunteer for three years. She joined the program with the aim to increase her knowledge in gardening and solve problems she was facing in her garden. As a novice gardener who inherited a flower garden next to her new home seven years ago, she was committed to do better with her garden. During this period, Ruby enjoyed her success of being able to grow vegetables and corns from seeds to maturity. Through that success however, the lack of prior knowledge led to some failures including one example she recalled when she grew corn and missed the harvesting time.

She said:

> I just didn't know when to pick the corn. [laughter] So I came out late and we kept on looking at size, we didn't pull back the plant to find out what the kernels look like and it was just... It was too ripe, so we gave it to the deer.

Before joining Master Gardener program, she tried different crops and gardening techniques with little success which is the period she called “period of failure or period of experimenting”. That period led her to join the Master Gardener program to increase her knowledge, and therefore, success in her gardening. From there she started her inquiry journey looking for answers. Her inquiry process was limited to reading resources related to gardening, watching YouTube videos, asking colleagues for suggestions of what can be done to solve her problems. Ruby assessed her decision to join the Master Gardener program as a success. She believed that she has increased her technical abilities of growing vegetables from seed until maturity. However, she didn’t mention any specific problem-solving skill she learned in the program. She only emphasized how well she thinks and does with her current gardening.

She said:

> Well, I can say that I successfully grow vegetables now and I kind of know how to start things from seed where I didn't know before was success that is. So, I would say that, is it 100%? I guess I would give myself 80% because... No, even higher, I would give myself 85% accuracy as far as being able to start something from seed and seedling and then grow into something productive. So, I'd give myself an 85%, it just depends on what I'm trying to grow.

Notecards were collected when Ruby used the online lessons to show what she learned through the program. She wrote in the notecard that she learned factors to consider when planning to use hydroponics in gardening. She named some factors that include water, pH, amount and length of lighting, and temperature of air and nutrients. She also added that she learned about skills required to conduct an inquiry.

4.4.2 Motivation and Value

Ruby’s motivation to learn more about gardening extends beyond the value she sees in acquiring knowledge to grow crops successfully. She also sees value in preserving her own produce for future use which is the reason that pushed her to learn how to do canning. She said, “I would say 100% benefit to me because, first of all, it proved that I could actually grow things and that's all I cared about. I've actually done some canning, so it's giving me some food.”

In addition, she also aims at sharing that knowledge with others. At the time of the experiment, she was using her gardening knowledge to teach students with disabilities (where she currently works for her fulltime job) how to grow crops. She enjoys making impact in her students’ life hoping that they would learning how to grow crops and save money that would otherwise be spent on buying food.

She said:

> Another benefit is that I'm able to teach others how to feed themselves. So even though they may not be into it, but at least they have that recollection, oh yeah, my teacher taught me, I could do this. I don't have to go out and buy plants all the time. I can regenerate from what I have and save money. So I think those are real big benefits.

On the other hand, in the post-interview she shared that although growing crops successfully is what she cares about the most, Ruby also is interested in seeing the final result from her experiment, even if it might turn out to be an unsuccessful experiment. Ruby thought that the type of experiment she performed for this study would be beneficial to her students. However, she was not sure if the time that it takes to finish the experiment would be feasible with her students because of their short attention span.

She said:

> And I just kept thinking, "Does it really take this long to do an experiment?" But I don't know whether I was just impatient or anxious to get to the worst. [laughter] But it just seemed long... My students have short attention spans as it is. So it would be up to me to make sure that they stayed on it and kept recording, but it's worth it.

4.4.3 Scientific Method

4.4.3.1 Past Experience Led to Hypothesis

In her experiment, Ruby chose to explore the effect of light intensity on plant growth. Her prior experience with hydroponics, in which she failed to successfully grow herbs, led her to choose a research topic that would help her to understand the role that light intensity plays in plant growth. Her choice was inspired by her prior unsuccessful experience in growing herbs using hydroponics. One of the challenges she faced with her first hydroponics kit were non-adjustable height of the light. She thought that light was placed too far from plants and her plants weren’t absorbing enough light to fully grow.

She said:

> So, the one part that pushed me the most was the fact that I had invested $200 in a kit from Williams and Sonoma… And actually, what I found out was that the lights weren't adjustable, so they were fairly high from the plant … and our herbs came out, but they were kind of lanky and weak, so I just wondered how much does that light intensity factor into the growth and sturdiness of the plant.

She hypothesized that different light intensity would affect lettuce growth differently. Therefore, she grew lettuce with different light intensity and kept other inputs the same. For instance, she kept light on 16 hours per day for both kits, she added same amount of nutrients in both kits as recommended and kept them at the same temperature. Concerning the light intensity, on one kit she kept the distance between lettuce and the light source at 12 inches while for the other kit, she kept the light at 8 inches. She then planned to systematically collect data on leaves length weekly. However, throughout the experiment which lasted nine weeks, she sometimes collected data earlier or delayed a day or two.

4.4.3.2 Experiment Design and Conclusion

During the data collection process, she measured the length of four leaves from plants selected randomly and calculated their average length. She kept track of the lettuce growth. Her worksheet showed that the leaves of the lettuce with high intensity light consistently had a higher average inch than leaves with low intensity light. She harvested older leaves on week seven, because the leaves were getting too old, which impacted the dynamic of her measurement and the average length of leaves with low light intensity. However, after two weeks, leaves on the high intensity light kit grew longer again. In her worksheet, she explained that inconsistency by writing:

> Although the sampling average of four leaves I measured were less than the sampling of the Kit A leaves for the first time, these leaves are 130 mm across and still looking a bit more attractive to eat than the control kit leaves…… First time that the average of four leaves have surpassed the more intense light kit leaves; however, the leaves curl under and don't look as robust as the more intensely lit kit.

After comparing average length of leaves from each kit, she found that leaves from the kit that received higher light intensity (kit B) grew longer and wider and that difference was consistent throughout the growing time apart from week 7 after she harvested older leaves. She, therefore, concluded that light intensity affects lettuce growth. At the end of her experiment, she also compared roots strength and found that roots of lettuce in kit B grew stronger than in kit A. She, however, did not explain measurements she used to assess roots strength. Finally, she compared the texture in which she found lettuce in high light intensity kit had a crunchy texture.

She said:

> Nevertheless, I found that the more intensely light kit, which was kit B, had a stronger root system, and the leaves themselves always grew a bit longer and wider, and they also had more texture than the kit that was not grown with such intense light at the beginning…… the texture of the less intensely grown lettuce was more smooth, and it wasn't as crunchy, so it kind depends on how you like your lettuce.

4.4.4 Scientific Reasoning

4.4.4.1 Abductive/Inductive Reasoning in Preprogram Stage, and Deductive Reasoning in Post Program.

When asked her problem-solving strategies, Ruby used one of her gardening challenges as an example. In the first interview, she demonstrated how she used abductive reasoning process to give a meaning to what might be the cause of weed growth in her garden.

She said:

> Out here where I live, there's a lot of weed seed growing around, and every year I find a new weed. At times I have felt, although I can't prove that the farmer across the field has affected my plants. So, he does some spraying and I'm not sure if that's drifted over and affected my plants or not but that's my theory.

Ruby also showed how she used inductive reasoning process to explore the best ways to germinate seeds. She tried different germination ways and make a decision out of a pool of observation she made. In the example quote below, Ruby demonstrated that she knows temperature could have influence on plan growth. Therefore, when she transplanted the seeds from a wet paper towel to soil, she put the seedlings underneath light and places some heat pads underneath the seedlings to raise the temperature.

She said:

> I just germinate the seeds in a plastic bag with some wet paper toweling, just to find out what my germination rate is. And then I would put the seed... Then put that little seedling into the soil and put it underneath light, but now I've learned to put some heat pads under things to help them grow because of that temperature factor.

In terms of interpreting her experiment, Ruby demonstrated that she mainly used deductive reasoning process. She hypothesized that light intensity would impact the lettuce growth. She set up both control and treatment groups. She measured the leaf length as her data, and compared the difference between the two groups. As described above in the section and experiment design, in week seven based on the data that she collected, Ruby concluded that light intensity has impact on the lettuce growth. Although the root system was not in her plan when she designed how she would collect the data at the beginning, she also made an observation and compare the root system for both control and experiment groups. The roots observation that she made helped her strength her conclusion to confirm her hypothesis.

After Ruby learned from her experiment, she explained her idea to conduct an experiment in the future where she explained how she combined what she learned from the light intensity experiment and other experience that she acquired from her everyday life, such as temperature and growing medium that have influence on seed germination rate. In defining her next hypothesis, she looks forward to conducting an experiment where she will compare germination rate of seeds grown outdoors and the ones germinated with hydroponics kit. The new hypothesis showed that

Ruby used both inductive (her prior knowledge in terms of germination) and deductive reasoning processes (the experiment that she did for the project).

She said:

> I guess one of my experiments might be to see if there's a difference between growing hydroponically versus in soil, and if you get two seedlings that are the same heights with the same amount of light, one hydroponic and the other in soil, and you take them out and measure the length of their root system... My hypothesis would be that the length of the root system for the hydroponics would be longer.

4.4.5 Inquiry-Based Learning Experience Through the Program

Ruby expressed her satisfaction with the learning process. She enjoyed being able to do hands-on activities in which she believed that hands-on actives help her learn better than just by reading or being told something. She also believed that her students learned better if she used hands-on activities. She stated, “I like workshops. I go to them. But if I had a class of students, of course, I would prefer to do a hands-on experiment than just have them read and talk about it.” The project also helped her appreciate the value of systematic data collection. When she reflected on how she acquired the information to solve problems by asking others and watching YouTube videos, she stated that she might not 100% trust the information she receives from others after the project as what she believed before.

She said:

> Well, I already said that because you can still take what other people's experiences and observations are as truth. But once you go through that process (conduct experiment), I think it stays with you better for one thing. You can read something and then forget about it, or read something and find a different truth. But once you do something, it just stays with you better.

This learning experience shifted Ruby’s views on how she acquires new information. She is more skeptical with regards to the quality of information she may be told and emphasized on questioning most of the information ones gets.

She said:

> Well, as I said before, if I looked at a video and somebody was saying, "This is what you do, this is why it happens," I know he's gone through his own experimentation to say that much. And just as this lady had said, transplanting hydroponics into soil is not successful, it's not that great, it just casts a lot more questions in my mind, where this experiment has made me think, you know, it's just not enough to read about it or watch a YouTube video.

Concerning the incorporation of scientific concepts in her everyday life, Ruby had different views during the pre- and post-interview. In her pre-interview, she explained that she incorporates scientific concepts by asking open-ended questions to her students. She also considered herself as a scientist because she asked open-ended questions.

She stated:

> Well, when I'm teaching the units on growing things and we're doing hands-on activities of growing and something goes wrong or something's happening to the plants, yeah, I address it as a scientist. I always leave an open question as to what do you think is happening? Why do you think this? So that whole process of getting them to think about what you see, what you get, what you can produce.

During the post-interview, she expressed a different view regarding her inclusion of scientific concepts into her everyday life. In her expression, after the project, Ruby found herself was not quite as scientifically inquirer as she thought she was.

She said:

> The other thing I was thinking back on, was your first interview and you said, "Do you think of yourself as much of a scientist?" And now when I think back on that question, it's like, "Oh no, I wasn't at all scientific." And I remember my answer was, "Oh, yeah." And then you said, "Well, how do you think of yourself as a scientist?" "Well, when we're done doing something, then I inquire, I ask my students questions," but that's not at all scientific. The questions come before the experiment and then... So I really feel kind of embarrassed by answering that, but at least I found that much out about myself [chuckle].

4.5 Findings for Leo

4.5.1 Prior Knowledge and Problem-Solving Experience

Leo grew up on a farm and started learning about gardening with his grandparents. He recalled one of the projects he participated in during his second grade as a kid. The project was meant to give students a baby food jar, a paper towel, and a corn kernel. Leo managed to keep the paper towel wet, and it germinated. He also saw how different approaches could be used to germinate a corn kernel. That experiment led him to be interested in different ways to grow things. For the past 35 years, Leo has been doing personal gardening with the aim trying something new every year.

He said:

> My personal gardening experience, it's always a learning process and has been since the beginning. I gardened with grandma and grandpa when I was a little kid, but what kind of changed the way I looked at was a project in second grade. They gave us a baby food jar, a paper towel, and a kernel of corn. And I was able to keep the paper wet and it germinated. So I was always interested in different ways to grow things. And then about 35 years ago, I got back into it again, dug up a space and planted the garden, basically knowing what I knew at the time. And I had mixed success, but as I got interested in, I looked at more ways to grow things better and try things that I had never grown before. I'm to the point now, I usually try something new every year. Typically, something I could try to grow in a container or something that I've never grown before, and then I can share my experience.

Leo used his prior knowledge in solving his gardening problems. His prior knowledge mainly came from the time he spent gardening, collaborating with his fellow Master Gardener volunteers, and read educational sites on internet. As a general principle, Leo solved gardening problems by starting with the least destructive option. He also acknowledged that he solely relies on his memory when trying to apply his prior knowledge to the current gardening.

He said:

> Typically, what I would do is first what we were taught in Master Gardener class, you try to do the least harmful, least disruptive thing first…If it's something that I have not seen before, typically I would reach out to my other fellow Master

> Gardeners. And I get opinions from them and get ideas on what I need to do next. Or maybe something that I haven't tried before, whether maybe planting a trap crop, but I would reach out for advice either through the Purdue website, or the University of Illinois website and my fellow Master Gardeners.

Notecards used during the online learning experience also showed Leo's prior knowledge before the project. After watching the online lessons, he learned that hydroponics requires the same needs as conventional gardens but offers more flexibility than conventional methods. He also learned how to identify plant nutrient deficiencies and choose the proper substrate for the crop being grown.

4.5.2 Motivation and Value

Leo is motivated to increase efficiency in gardening by using minimal space areas in growing crops so that he can teach others to grow the vegetables even if they may think they don't have enough space for gardening. He tried new things approximately every year hoping to find something that can help others to do gardening efficiently. Things he tried were either growing techniques that he had not tried before or new crops he had not grown before.

He said:

> A lot of times, because my interest is in small space gardening and sharing that information, I look at different ways, different types of containers. So, I like to grow things that maybe are bred specifically for containers to tell people, you don't have to have a backyard, you can grow things. I've experimented with a few different systems, and as I mentioned, when we first communicated once upon a time I did build a homemade hydroponic system, very primitive. But I did have some results. I grew a few cucumbers in it, for really what I knew and what I put into it, it was probably a success.

4.5.3 Scientific Method

4.5.3.1 Past-Experience and Curiosity Led to Hypothesis

After trying a primitive hydroponics, Leo interest in exploration mentality never stopped. He had a lot of questions regarding how efficiently hydroponics can be used in growing crops. He even went further trying to understand how commercial hydroponics work but as he knew that they use complex systems, he decided to try to understand how different components work step-by-step. Knowing the complexity of commercial hydroponics, he focused on exploring the effect of one component at a time.

He said:

> Well, I know it, because I've always wanted just a little bit how commercial hydroponic operations grow because I follow a lot of these vertical growing operations and so forth. And I guess from a conservation perspective, and a perspective of simplicity, I was a little bit curious, and I had a lot of questions in the beginning.

Once he was given the opportunity to explore something of his choice during the inquiry-based project, he chose to explore effects of water type on plant growth. Based on his previous gardening experience and prior knowledge that he learned from volunteering in Master Gardener programs, his hypothesis was how types and quality of growth medium affect nutrients availability for plants. He assumed that different types of water, such as distilled water and mineral water, might act differently with regards to nutrient availability for plants.

He stated:

> I know we'd mentioned distilled water. We talked about the pH varying and the distilled water a little bit from batch to batch. But I think the thought was, "If mineral water has more things in it... " So my thought was, I know that in soil-based gardens, the type and quality of the soil, affect the amount of available nutrients to the plant. Clay-based soils has significantly less available nutrients. So I kind of wondered, does water do the same thing?

Leo hypothesized that “type of water used impacts growth”. The experiment lasted for eight weeks, and he collected leaf length data on weekly basis while he measured the yield weight at the time of harvesting.

4.5.3.2 Experiment Design and Conclusion

Leo used two hydroponics kits to perform his experiment. He used bottled mineral water in one kit and distilled water in the other. He then kept all other inputs the same by following the growing guideline provided by the hydroponics kits manufacturer. He had a 60% germination rate for kit A with mineral water for drinking and 75% germination rate in kit B with distilled water. Leo did not think that different type of water had an effect on germination rate, because the plants seemed to catch up at the end of the experiment.

He said:

> Overall, in the beginning, it was a little touch-and-go. One bed, I didn't get a very good seed germination out of it, about seven of 12, and nine of 12 with the other. Do I think that has anything to do with the water used? I don't think so. The one with distilled water, I got nine out of 12 germination and the bottled mineral drinking water, I only ended up with seven plants. And they seemed to progress a little more slowly in the beginning, with my measurements, but as the experiment progressed, they seemed to catch up.

After getting a low germination rate, he consistently kept all inputs the same and showed an understanding of the value of keeping all input the same and only change one input (in this case water type). For instance, he was filling up the hydroponics kits with two and a half liters of water, adding 5 milliliter per liter of the plant nutrients he had. He continued explaining how he measured the yield weight to determine the difference among the performance of the two kits after eight weeks of growing. Meanwhile, he also measured leaf length every seven days to assess the growth progress of lettuce leaves. Although there was a small difference between distilled and mineral water at the end of the experiment, Leo believed that the difference was too small to make a conclusion that distilled and mineral water yielded a different result.

He said:

> I have digital scales. So, I used a bowl, I allowed for the tare weight of the bowl and put, and weighed the harvest. So, a lot of lettuce leaves don't weigh a whole lot. So, out of bed A, I got just over half a pound, 0.51. And out of the second bed, which actually had filled out a little more with seven plants, I know, I believe... It's in my data. I believe it was about 0.47. So anyway, I calculated the yield per plant, and really, there was only a difference of about 3% in the two beds. To me, that's statistically not significant.

4.5.4 Scientific Reasoning

4.5.4.1 Inductive Reasoning in Preprogram Stage, and Apply Deductive Reasoning during Post Program

During the pre interview, Leo demonstrated inductive reasoning while he explained how he solved his gardening problem like pest control. In the case of pest control, he explained how he used the knowledge he acquired to protect his crop by covering them with a mesh row cover. He had a successful experience of growing plants that did not require pollinators by using a mesh row cover to protect them. Then, he applied the technique with a bit of modification to grow squash and cucumbers, which are plants that need pollinators, and he was happy with the results.

He said:

> Well, what I do now, because I know anything that does not require a pollinator, I put a mesh row cover over it. And that's for beans, legumes and things like that. That's been extremely successful. For other plants, and I think my biggest problem has always been with the squash and the cucumbers. Typically, the first thing I do would be to use, well, I'll cover them until they start the bloom. And then once I get the blooms, I will take the cover off, obviously for the pollinators. I will use Neem or insecticidal soap as a beginning. And that seems to work fairly well.

During the post interview, Leo explained his understanding of the value on conducting an experiment through the process of deductive reasoning. He also appreciated how the project asked him to document the whole experiment process, which helps him to be able to reflect on what he had missed before when he tried to solve problems.

He said:

> I can do this again in the future when I get curious because now, I have a true documented process that I can follow. Like I said, that was just something you did. I knew the steps and I did it. But now I have a documented process for how to conduct an experiment versus what I had never had before. And I think if you're looking for true measurable results, you've got to have all the factors in your experiment be identical, or your data is not any good.

Leo also looked forward to doing other experiments to explore and hopefully solve problems he had in the past about gardening. For instance, he had a blossom-end rot in his tomatoes in the past. Leo was looking forward to do an experiment performing a comparative study to explore what might have been the cause of the problem. This showed Leo had combined inductive and deductive reasoning processes at the end of the project.

He said:

> I got involved in something last year and I would like to test it. I was starting to see blossom-end rot on the tomatoes, but more importantly, I had never seen blossom-end rot on squash before. I did some research. I didn't know how to correct that. So, really what I determined was that we were getting so much rain, it was washing the nutrients out of soil in my raised beds, because raised beds had no bottom in them. So the nutrients were just leaching out. So I went and added the iron supplement to it, and it corrected it, but there was no scientific process to it. I would like to test those side-by-side, or test the amount that I used, I followed directions on the package. Okay, that's a good place to start, but I could have run side-by-side tests based on using different levels of the fertilizer supplement to correct the problem.

4.5.5 Inquiry-Based Learning Experience Through the Program

Leo appreciated the hands-on nature of the learning experience that fits his natural inquisitive character. As a gardener, he also enjoyed going through the whole process of growing lettuce and he would love to do it again going forward.

He said:

> I don't learn well with extremely structured learning. And to me, that from a learning perspective, I think that makes me a better learner than somebody else just telling me to do it. You provided the tools, and just being naturally inquisitive and putting my hands on it as I said, I'm a very visual learner, let me put my hands on it and see how it works. I will retain the knowledge better and I'll be more committed to the process.

In addition to the structure that let Leo put to work his inquisitive abilities, he also appreciated the freedom to choose the topic he was already interested in and were eager to know more about which increased his motivation.

He said:

> I think that because the experiment itself is structured as you said, but I think that by looking at it and thinking about it, instead of doing what somebody else is interested in, you [participant) had the opportunity to look at it, and I think that because it's your experiment and that you're using your hypothesis, I think you treat it more as a learning experience than just, Okay, I've got this class, I need to complete this project and report the data.

4.6 Findings for Bella

4.6.1 Prior Knowledge and Problem-Solving Experience

Bella grew up on a farm. She started gardening while she was a child with her mother and did not stop ever since. She recalled growing crops on straight rows and having hard times hauling weeds out of soil because of hard clay soil in which they were growing crops. She is currently growing her crops on a sandy soil using raised beds, containers, and home hydroponics.

She said:

> I started out as a child with my mother's garden, with straight rows of things growing, and it was a hard clay soil and it was very difficult to even haul weeds out of it. Now I'm gardening in a sandy soil, which is entirely opposite, and we use raised beds, containers, growing some things in the ground. And of course, we already have two little hydroponic units.

In her current gardening experience, she enjoys trying new things like gardening things and she is keen in knowing better regarding gardening. That is also the main reason she joined the

Purdue Master Gardener program. During her 13 years in the program, she learned a lot regarding gardening techniques. But what she considers as a big success is her achievement in creating a group in her county which created a platform for sharing gardening knowledge in her county. She was inspired by the lack of a such opportunity in her county yet Master Gardener volunteers like her, need to keep learning about gardening and increase their volunteering and learning hours as required by the program.

She said:

> Well, I really enjoy the purpose of sharing the knowledge, sharing the gardening knowledge. At first, it was difficult for me to get the educational hours when, because everything being tucked at the very northern part of the state as we are, all of the educational hours were available at least 30 miles distance and usually cost $20 to go to. And so I got to thinking about it and realized that everybody had the same problem. So I started a program in our local county called Brown Bag Series which is four times a year…And it was fun, people enjoyed it.

During her current gardening, she identified two main problems she faced in her gardening experience. One was pests and the other was water quality. She identified cabbage worms and white flies to be her major challenge for her crops. She also identified hard water (alkaline water) to be the other challenge for her hydroponics kits because she once lost the whole crop trying to fix the problem of hard water that she used for her hydroponics kit.

In the pre interview, Bella explained the steps she took while trying to solve her gardening problem. Mainly, she uses online resources to learn the options she can apply to solve the problem. She also asks her fellow Master Gardener volunteers for suggestions. In the pre-interview, said:

> Well, I try to study the options using online or Purdue, and other places... So research is first…and then try to do something about it, what works for me… Sometimes I’ve gone to other master gardeners... My fellow master gardeners are pretty good at helping me out with questions. I ask them a lot.

Notecards used during the online learning experience showed Bella’s prior knowledge before the project. Among what she learned after the project included plants need proper nutrients to thrive, and the plant symptoms will signal which nutrients are missing and how temperature affects the rate of growth. She also learned that using the scientific method in a controlled indoor hydroponics should produce solid factual testable information to get the most out of gardening efforts.

4.6.2 Motivation and Value

Gardening has been a lifelong journey for Bella since childhood. She is motivated to be a gardener because it shows the value of who she is. She enjoys trying different techniques to increase efficiency in gardening and being able to share gardening knowledge with others. In addition to getting new knowledge and sharing that knowledge to others, Bella's mental health also has been improved from gardening, because during the wintertime, the light from hydroponics reduced her seasonal depression. She also appreciates fresh produce all year round. She stated:

> Yeah. So for me, it was very fun to be able to share that knowledge. And of course, anytime I present anything, I always learn more. So that was part of it too…. And I've discovered that I no longer have seasonal depression, because every day I'm bathed with that full spectrum light. And it's wonderful to have little tomatoes all the time.

4.6.3 Scientific Method

4.6.3.1 Past Experience Led to Hypothesis

Throughout her lifelong gardening experience, Bella enjoyed a lot of success with growing crops and sharing knowledge with others. However, her current experience with hydroponics farming came with a challenge she was still straggling to solve at the time she participated in this study. She was using hard water to grow her vegetables in a hydroponics system and her vegetables were dying. She believed that by conducting an experiment to change her hard water, she will be able to solve that problem. She said, “My water is way too hard. And so my hypothesis was that if I would take my well water and treat it with some acid, that I could adjust it and make it workable”. In other words, she was trying to find ways to treat her hard water to make the water suitable for her plants to grow.

4.6.3.2 Experiment Design and Conclusion

During her experiment, Bella conducted a comparative experiment using two kits. She used distilled water in one kit and use hard water treated with acid aiming at reducing that water alkalinity. On her worksheet, she explained her design as follow:

> Lettuce needs a balanced pH level of 5 to 7 to grow well. This test used distilled water in Unit A, and well water, pH level 9.5, with 2 teaspoons of 5% acidity white vinegar to bring the level down closer to neutral in Unit B.

She collected data on leaf length every four days. At the beginning of her experiment, Bella started by treating water with white vinegar until after germination. When she saw the edges of lettuce leaves started to dry, she rinsed and renewed growing solution. She added a solution she bought from Amazon. After she switched to the solution that she bought from Amazon, she realized that her crop wasn’t perform as well as the distilled water kit, then, she switched to citric acid. She also indicated that switching to citric acid was based on an expert’s suggestion. Yet, after couple days later, she observed the plants were still not doing well compared to the distilled water kit, she switched back to the solution she bought from Amazon again, which continued to improve her crop. She was happy by the result, because the lettuce in the hard water kit finally “caught up” with the distilled water kits. She explained this process by saying:

> At first, the one I treated was way behind the second one, the one with the distilled water. It grew about half as fast, and it didn't germinate quite as well... And then I used a solution I bought off Amazon that was specifically designed to add acid to

> alkaline water… And so I switched over to some citric acid in a powder form that I used to can fruit, and that didn't quite work. So I switched back to the first... The solution I got from Amazon. And in the end, the second one almost caught up to the first one. So I had changed a couple of things. If I could see that I wasn't succeeding, then I needed to change.

Overall, her crop in kit A, which is the one that used distilled water, grew faster and longer than lettuce in kit B. She measured average height of leaves and found that crops in kit A were longer. Because she did not get the desired effect that she expected, she changed the solutions few times during the experiment. She said: “Obviously the water with vinegar in it was still too alkaline and the plants in Kit B did not thrive.” However, she acknowledged that her findings might not be conclusive because of other uncontrollable factors. For example, she was using hard water in kit B which contained a lot of nutrients. She agreed that there might be a possibility of having a lot of calcium nutrients which as a result would have hindered lettuce nutrient absorption and slowed their growth. She, therefore, admitted that if she were to repeat her experiment, she would also consider doing analysis of calcium element presence in her water.

She said:

> Besides pH, there is a calcium balance, and there is going be some kind of nutrient in the water if there's solids in there. So, it would be nice to know what I'm really working with because there's so much is unknown.

4.6.4 Scientific Reasoning

4.6.4.1 Reasoning Process in Preprogram Stage, and Abductive/Inductive Reasoning after Post Program

During the pre-interview, Bella described her problem-solving methods by following a trial-and-error approach, which mainly were abductive reasoning process, and looking for the solution that works when solving the problem.

She said:

> Well, I had problems with my hydroponic unit recently. It was not thriving. And I couldn't figure out what was wrong, and I studied the options and I finally realized that I was using my tap water and that our water is so hard that I was giving my tomatoes alkaline water. Because I went online at what do tomatoes need and stuff. So I actually got some pH strips and checked it, and it was nine, which is very alkaline. And so I cleaned it all out and washed everything and started over and I've been using, distilled water since then. And everything's fine.

During the post interview, Bella also demonstrated that she did not change her trial-and-error thinking in her future gardening. Yet, she stated that the experiment she conducted helped her to think systematically and taught her that the first answer might not always be the right answer. As a result, she looked forward to comparing evidence and use the one that works best. Based on what she did for her experiment, she did not demonstrate skills required to conduct a scientific experiment, such as following the experiment design for control and treatment groups.

She said:

> I do a lot of research... But I usually quickly research it and move on. I'm usually content with my first right answer. This [the project] taught me to slow down. And the chart was good because it gave me solid evidence of what was working and what wasn't working… for me, the process of finding the best way to grow is as important as getting the right vegetables.

Also, When Bella mentioned ways how she would approach her gardening problems after the project ended, she continually showed that she would use trial-and-error approaches that incorporate with abductive reasoning process. For example, she mentioned how she saw some of her vegetables were not doing well. She then removed them from the hydroponics unit and planted them outdoors in soil.

She said:

> Well, I already sort of did with the big growing unit that my sister gave me... It came with some seeds, and so I planted some of those up and then I went to my own seeds and I added Coleus and Petunias and different herbs. I tried cucumbers. That didn't work. I finally pulled them out of the hydroponics and put them in soil next to the hydroponic, so they could get the light, and that's working.

4.6.5 Inquiry-Based Learning Experience Through the Program

Bella enjoyed the overall experience of learning with a less structured lessons. She prefers having little guidance on how to proceed with her learning experience and be the one imposes the structure to follow by herself. As she stated, the opportunity to try things and learn throughout her failure is what makes her a better learner.

She said:

> Or having more frequent... Yeah. Probably not having structure because I am going to flail around until I figure out something. And I may make several wrong turns while I am on the way, and I always learn something from them.

4.7 Findings For Hope

4.7.1 Experience Growing Crops

Hope is a gardener who enjoys gardening and has a big garden to grow much of the food for her and her family eat throughout the year. She also grows vegetables using hydroponics in addition to other plants that she grows outdoors. She prefers growing vegetables with hydroponics system because, for her, it is easy to manage and predicable. To Hope, she believed that hydroponic system is set up to be success.

She said:

> So hydroponics, I find very easy. There's no guess work involved, the lights are set for a certain amount of time, nutrients are always the same, you don't have to pollinate based on what kind of seeds you're growing. It's just easier.

Notecards used during the online learning experience that showed Hope’s prior knowledge before the project. In the notecards, she wrote that there are different ways of growing plants hydroponically. She also learned that the main benefits of growing food hydroponically are environmental, health and financial. In addition, she learned that we should make a hypothesis, collect data on a consistent basis, see if our data supports the hypothesis.

4.7.2 Motivation and Value

Hope is mostly motivated by teaching others to grow crops and she spends most of her volunteering time doing so. She mainly teaches at schools and community outreach programs. Additionally, Hope also grows food in community gardens that are used to feed people in need through food banks. Helping others in need is the main reason that she joined Master Gardener program.

She said:

> I wanted to help my community…. So I have gone on into the high school and worked with both growing and aquaponics. And then I have taught hydroponics at a community outreach program. And I also work in a community garden where we grew 990 pounds of food and donated it to a food bank this year.

4.7.3 Scientific Method

4.7.3.1 Past Experience Led to Hypothesis

Her experience in growing food indoors and outdoors made Hope wondered how to effectively use her water. She was normally using different types of water for indoor and outdoor crops. As she was using tap water for outdoor gardening and reverse osmosis water for hydroponics gardening, she wondered what could happen if changed that.

She said:

> Well, because when I grow my plants inside, I typically use reverse osmosis water. And when I grow them out in the garden, I usually use just tap water from outside, my hose. And so I just wondered which one would actually work better.

Hope hypothesized that “Plants will grow faster in Reverse Osmosis water over Hard Water” and used same inputs as recommended by manufacturer for both hydroponics kits. She only changed the type of water as the variable that she wanted to test. She used tap water in one kit and reverse osmosis water in the other kit.

4.7.3.2 Experiment Design and Conclusion

During her experiment, which lasted eight weeks, Hope collected data on a weekly basis. She measured three different leaves length on each kit to indicate the plant growth. For the first three weeks she didn't see any difference in leaf length between the two kits. However, after the third week she started to see that leaves in the kit with reverse osmosis water were growing faster than the kit with tap water. Therefore, she concluded that plants grown in reverse osmosis water grow faster than those grown in hard water.

She said:

> So, what I did is I found that the hydroponic system did not grow at the same speed. And so, I took one leaf from the area where it grew fastest from each plant or from each system, one from where it grew the slowest, and one where it kind of grew in the middle. From each of them, that way I was getting equal results… The experiment went great. I did not touch my, once I planted it, all I did was I added the nutrients in water and that was it. I actually got the results that I thought I was going to get. So, it did grow faster in the reverse osmosis water.

4.7.4 Scientific Reasoning

4.7.4.1 Reasoning Process during the Program

During the pre-interview, she explained how she solved her gardening problem by using her prior knowledge, which implied that she used inductive reasoning process. She used her years of gardening experience and intuitions to seek the patterns of how things work to make a conclusion about a given situation. She mostly does that on her perennial crops in which she is most familiar with or to some problems she consistently faces.

She said:

> I can look at a plant and say, "It probably needs something else," and test my soil. Sometimes I just have to say, "Well, I guess this is going to be a bad crop this year." Because fruit trees, you can't control a lot of things. And so some years are just bad. If we have an early frost, I have a bad crop.

During the post-interview, she explained how she appreciated the experiment, which suggested that process helped her use deductive reasoning, in solving her gardening problem. The most important thing for her were to control input and being able to make a conclusion. As a result, she appreciated the knowledge that she had learned based on the data were collected, and conclusions were made. She acknowledged that scientific method process is the best way to distinguish opinions from facts.

She said:

> So I think it was actually better for me to do the experiment myself because sometimes I don't think people have it in a controlled environment. And so by having it controlled, I was able to actually tell if the water was making a difference or not. Where if I'm just talking with my colleagues and they tell me this worked for me, but they didn't do it in a controlled environment, you can't really tell why it worked for them.

In the future, one of Hope's ideas is to use what she learned from her experiment to answer how plants respond to light exposition at different length of time. She expressed her thinking by saying "I would like to experiment with the amount of time that the lights are on to see if that makes a difference or not." The experiment prompted her to inquire more hydroponics after she combined her prior knowledge and gardening experience, and what she learned from her experiment.

4.7.5 Inquiry-Based Learning Experience through the Program

She appreciated the module structure is flexible, so she would be able to listen the content on her convenience without waiting for others or having one designated time where everyone should adhere to. She said:

> So, for me, it was easier because I was able to listen to them one right after another when I had time. And I travel a lot, and so because I travel so much it made it easy that I could listen when it worked for my schedule instead of when it worked for everyone. So I liked that way. She also appreciated the ability to work on topic she was already interested in and wanted to know more about. That context made her want to know the outcome of her experiment and made her keep going. She, therefore, put effort in the process to make sure everything goes according to her plan.

She also said:

> So I would say that for me it's easier to work on something that I'm interested in to find the results rather than something that I'm just told to find the results. [laughter]. So if you would have told me, turn your lights on for 12 hours on this plant and 16 hours on that plant. I would have been like, "Okay." And I really wouldn't have cared about the results as much as when I chose what I needed to know. And it was something I was interested in.

4.8 Cross-Case Analysis

4.8.1 Prior Knowledge and Motivation

All four participants had previous experience in gardening where they were trained in growing and maintaining crops. They also had experience in growing vegetables using hydroponics system. In addition to their passion for gardening which made them join Purdue Extension Master Gardener program, they all see value in sharing the knowledge they acquired in the program with communities they live in. Mainly, they all got training in gardening techniques, crop maintenance, and post-harvest handling techniques. Two participants, Leo and Bella, especially expressed their passion for continuously trying something new to improve their efficiency in their gardening. Yet, while Leo focuses on improving small space gardening efficiency and teach others how to efficiently use their small space in gardening, Bella focuses on trying something new in general as long as she learns and is able to produce food.

Another similar characteristic for all four participants is their involvement in sharing knowledge through teaching. However, what motivates them are different. For instance, Bella was inspired by lack of close places where she and her fellow Master Gardener volunteers would get educational hours. Leo on the other hand, was inspired by teaching people to efficiently use small space for producing their food through gardening. Ruby, who is a special education teacher, was motivated by teaching her students to grow vegetables so that they can produce their own food and minimize money they spend on food in grocery stores. Finally, Hope has two main focuses regarding where she shares her gardening knowledge. One is in school settings where she teaches students to grow vegetables using aquaponics system. The other one is community outreach where she teaches the public how to grow crops using hydroponics system.

4.8.2 Scientific Method and Reasoning Process

During the pre-interview, three participants, Ruby, Leo, and Hope, expressed how they solve gardening problems using either inductive and/or abductive reasoning. For instance, Ruby used both inductive and abductive reasoning process when she reflected on what she believed how weeds appear in her garden (abductive reasoning process) and how her herbs did not grow well due to non-adjustable lights (inductive reasoning process) in a hydroponics. At the end of the project, during the post interview, all three also demonstrated the understanding of the role scientific methods plays in both recognizing and solving the problem, and/or answering their curiosities. They followed all steps of scientific inquiry that included defining a hypothesis, determining the variable of interest, systematically collecting data, and performing a comparative analysis. Conducting a scientific experiment also helped them use deductive reasoning process to interpret the results. However, they did not go beyond comparing means of the data collected without any other statistical analysis. This showed that the three participants applied deductive reasoning to interpret the results for their experiments.

On the other hand, Bella kept her focus on practical, abductive reasoning while trying to solve her problem of interest in both pre- and post-interviews. During the pre-interview, she demonstrated abductive reasoning by explaining how she solved her gardening problems regarding hard water. She explained how she used to assume that when her crops were not thriving, it was because of the hard water. Therefore, she emptied the whole water and refilled the container with new water to continue growing. Instead of understanding the problem, she focused on the practical strategy that worked for her to solve the problem. During the post interview, she again demonstrated the same reasoning process, abductive reasoning. Her experiment aimed at reducing the alkalinity of water because she assumed that once the alkalinity is neutralized, her crops will thrive.

The three participants, Ruby, Leo, and Hope, who demonstrated abilities to correctly use scientific methods to conduct experiments also illustrated more complex reasoning processes at the end of the project. During the post-interview, they combined their results with inductive or/and abductive reasoning to define hypothesis that they wanted to use in conducting future experiments. On the other hand, Bella, the participant who demonstrated a trial-and-error approach had shown less complex reasoning process. After the project, her future hypothesis still aligns with trial-and-error approach. This implied that very possibly, she will continually apply abductive reasoning to solve problems in the future.

4.8.3 Learning Experience

All four participants enjoyed the hands-on nature of their learning experience where they were able to put into practice what they just learned in the module. They were confident that after a theoretical part of the learning process, the hands-on activity was important to reinforce the knowledge gained in the real-world context. In addition to the hands-on activities, all four participants enjoyed the ability to choose the topic that matches their interest while conducting their experiments. The ability to choose the topic that matches their interest helped to solve problems they were currently facing like in the case of Bella. As for Leo and Ruby, guided inquiry process gave them an opportunity to explore their curiosity based on the problem they had previously. Hope wanted to investigate more about the water that she used in her garden with the hope to increase water efficiency moving forward. As a result, the value participants perceived in the topic they chose to investigate has been an important factor for all participants to persist while doing their experiments. Moreover, three participants who demonstrated scientific thinking by conducting a scientific experiment using a deductive reasoning, understood the value of systematic data collection and they look forward to continuing to investigate more in the future.

CHAPTER 5. CONCLUSION

5.1 Overview

This chapter summarized the three conclusions of this study. Three main topics guided conclusions in this study as follow: (1) Deductive reasoning that aligns with scientific thinking does not develop naturally; (2) When adults are given the opportunity of self-direction learning and materials focused on using their previous experiences to solve a real-world problem; and (3) Participants appreciated the value of systematic data collection and analysis, and they expressed intent to apply them in the future. This chapter also includes implications, and recommendations for future research.

5.2 Purpose of the Study

The purpose of this study was to explore and describe Purdue Extension Master Gardener volunteers' scientific thinking, learning experience, and intentions to apply scientific thinking throughout and after a home hydroponics inquiry-based project. This learning project was designed to help participants practice their scientific thinking. This research was conducted using a qualitative research method approach.

5.3 Research Questions

The research focuses on the following research questions:

1. How did Purdue Extension Master Gardener volunteers demonstrate their scientific thinking in the inquiry-based hydroponics project?
2. What were Purdue Extension Master Gardener volunteers' learning experiences in utilizing the online module for learning about home hydroponics and inquiry?

3. How did participants intend to apply scientific thinking beyond the inquiry-based hydroponics project learning experience?

5.4 Conclusions and Discussion

5.4.1 Scientific Thinking Demonstration

Conclusion 1. Deductive reasoning that aligns with scientific thinking does not develop naturally. It therefore needs to be facilitated through learning. Other forms of reasoning (inductive and abductive reasoning) align directly with every day's reasoning.

To demonstrate scientific thinking, individuals use scientific knowledge (prior knowledge) and reasoning processes that permeate the field of science (Kuhn, 2002). Newton and Robert (2004) and Zimmerman (2000) refer to these aspects as domain-specific knowledge and domain-general strategies, respectively. In this study, scientific thinking is defined as combining both domain-general (scientific methods and reasoning processes) and domain-specific knowledge (prior knowledge and experiment). Domain-specific and domain general knowledge are used to complement each other in a way, such as prior knowledge can inform the setup of the hypothesis and play a part in the interpretation of the experiment's findings as the conceptual framework (Figure 1, section 2.9) has shown.

Inductive and abductive reasoning occur naturally. Prior to the learning experience, participants demonstrated either the use of inductive and/or abductive reasoning in solving their gardening problems, but no deductive reasoning process was observed. The learning experience, particularly guided inquiry experiment design and, helped them use deductive reasoning through conducting an experiment in the project. This aligns with the findings of Kuhn (2010) and Zimmerman (2000) who found that inductive and abductive reasoning align with everyday reasoning. And researchers Dunbar and Klahr, 2012 and Kuhn, 2010 found how scientific thinking is developed through using prior knowledge and conducting an experiment using a deductive reasoning.

Kuhn (2010) pointed out that scientific thinking includes four phases, which are inquiry, analysis, inference, and argumentation. In this study, inquiry, analysis, and inference of scientific thinking were observed when participants defined inquiry, generated hypothesis, designed their experiments, and made conclusions out of the findings. During the "inquiry" phase, participants were able to formulate a question and decide a plan for data collection, recognize the question relevance to theory, and systematically accessed the data. This phase "inquiry" was described by Kuhn (2010) as the most important phase because it shapes the direction of subsequent phases. The second phase "analysis" was performed by seeing patterns among the data, make comparisons, and representing evidence resulting from their experiment (Kuhn, 2010). All participants who demonstrated scientific thinking were able to achieve the three tasks that identified by Kuhn (2010) in the second phase. The third phase "inference" was done by using outcomes from phase analysis to draw a justified claim.

Overall, demonstration of scientific thinking through domain-specific knowledge and domain-general strategies aligned with the findings of Niaz (1994), Schunn and Anderson (1999) and Zimmerman (2000), who concluded that expertise in scientific reasoning covers both domain general and domain specific skills. Likewise, John Dewey's work focused on applications of constructivism theory in inquiry-based learning in which learners build upon their prior knowledge to engage in inquiry as a tool to practice reflection in problem-solving (Dewey, 1923; Santrock, 2017).

One participant demonstrated inductive and abductive reasoning during the pre-interview and continued to demonstrate the same reasoning throughout her experiment after the learning experience. Her prior knowledge informed the experiment which she conducted. However, the experiment focused on trial and error demonstrating abductive reasoning.

Figure 3 illustrates the use of domain-specific knowledge (prior knowledge and knowledge that participants learning in the project) and domain-general knowledge to conduct scientific reasoning. The flowchart showed the hierarchic relationship among prior knowledge, motivation, scientific methods and reasoning process. Motivation was identified as an important component to help learners conduct scientific reasoning in this study besides the domain-specific and domain-general knowledge. Different types of reasoning processes were observed in different stages of scientific reasoning.

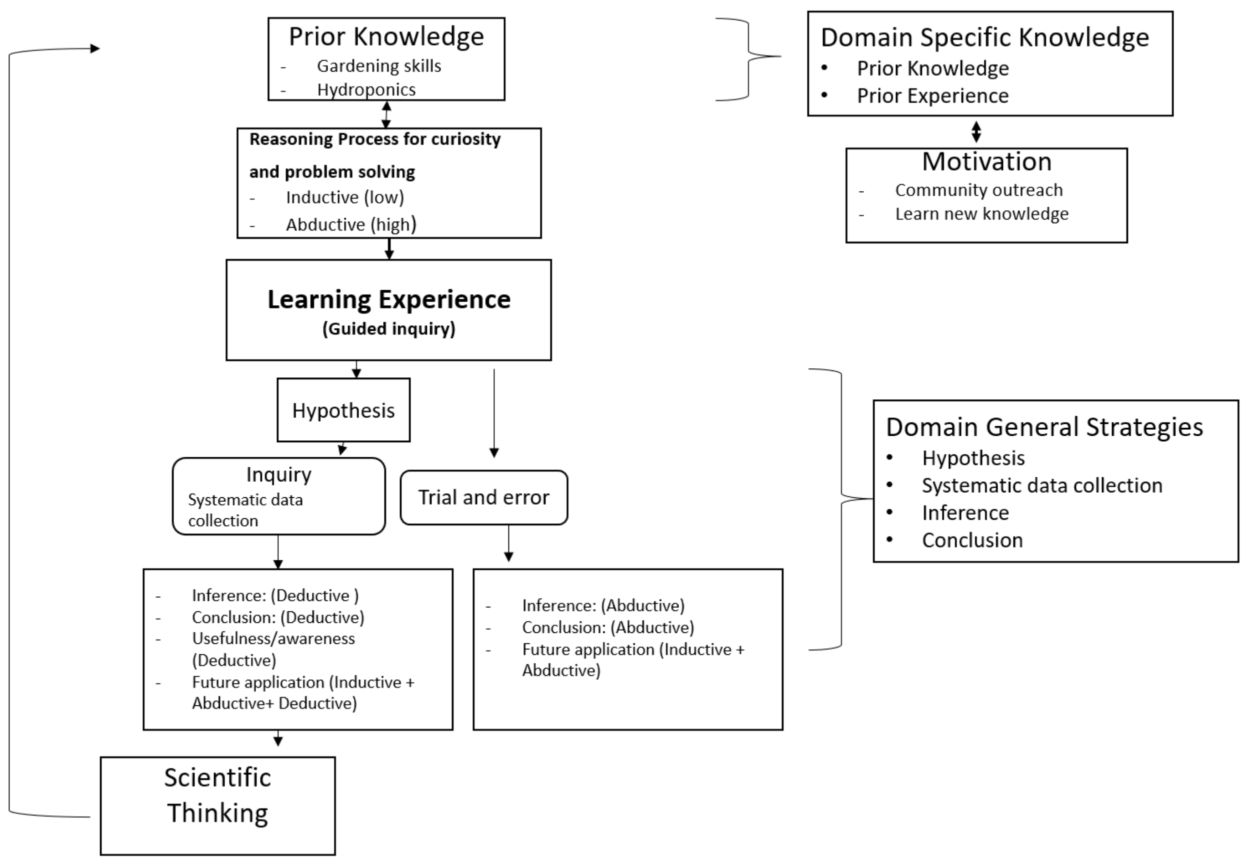

Figure 3. Scientific Thinking Demonstration Diagram

As Niaz (1994) stated, domain-specific knowledge is characterized by the concepts that individuals develop about phenomena from the fields of natural sciences. Those concepts were identified in this study as prior knowledge associated with gardening skills and use of hydroponics. Domain-general strategies, on the other hand, are characterized by reasoning and problem-solving strategies that were identified in this study in two different ways. First, prior to the learning experience, participants described their reasoning while solving problems which exclusively implied either inductive or abductive reasoning for all participants. These findings align with Kuhn (2002) who stated that inductive reasoning is associated with people's everyday reasoning. Second, after the inquiry learning experience, three participants described the process of how they conducted an experiment by using scientific methods. They demonstrated using deductive reasoning in problem-solving through conducting the experiment. As deductive reasoning process was not observed in three participants' everyday problem-solving routine until they conducted the experiment for the project, it led to the conclusion that deductive reasoning does not come naturally, and it needs to be intentionally facilitated.

A Systematic data collection led by deductive reasoning allows learners to define the hypothesis that aligns with the problem they want to explore. Therefore, they set boundaries for the data to collect and the analysis to be performed. The results of such an experiment can therefore be generalized to other situations similar to the one studied. Instead, trial-and-error experiments are performed when the learner assumes the possible outcomes of the experiment and assumes the method that leads to the outcome. Once an assumed method fails, the learner assumes the following method until desired results are achieved. Therefore, no systematic data collection or systematic analysis. However, trial-and-error is commonly used in everyday life because of its convenience.

Experiments that align with deductive reasoning have limitations on time and resource consumption, in addition to requiring a specific set of skills.

Motivation plays an important role in the inquiry phase (Kuhn, 2002), especially in terms of asking questions and generating hypothesis. Motivation is highly associated with the participants' prior knowledge and experience of gardening and hydroponics. Motivation also has impact on conducting an experiment, especially in terms of finishing up the process. To sum up, motivation appeared to be another important factor that contributed to the use of prior knowledge and scientific methods to solve problems through scientific thinking as it was detailed in next section (5.4.1). In addition to domain specific and domain general knowledge, the findings from this study suggested an additional component, motivation, should also be added into the perimeter when developing scientific thinking.

5.4.2 Inquiry-based Learning need motivation to promotes scientific thinking

Conclusion 2: When adults are given the opportunity of self-directed learning and given tangible resources and instructions to do their experiment, they were motivated, and they applied their previous experiences to solve a real-world problem.

For the second research question, the conclusion about the learning experience followed Knowles (1980) adult learning theory assumptions that include independence and self-direction, use of prior knowledge while learning, intrinsic motivation, and real-world, problem-centered instruction. Participants enjoyed being given opportunities to explore topics they were already inquisitive about related to gardening. This led to intrinsic motivation that drove their desire to understand how things work which led them to systematically collect data, make a conclusion, and take an action to solve problems.

Motivation played a big role in leading participants to perform scientific thinking while doing their experiments. Participants who demonstrated scientific thinking expressed appreciation of the independence and self-direction in their learning experience. For example, Hope appreciated being able to choose and work on the topic related to the results she cares about and has genuine interest in. Likewise, Leo appreciated getting a chance to work on a topic he was already curious about. These data align with Knowles (1980) adults learning theory assumptions stating that adults learn better when they have independence and self-direction or when they are working on real-world, problem-centered instruction. Also, Harlen (2013) mentioned that developing understanding through learners' own thinking and reasoning has many benefits for learners: First, enjoyment that comes from personally finding out something they want to know. Second, seeing for themselves what works rather than just being told is satisfying and, at the same time, stimulates curiosity about the world around them. Third, developing progressively more powerful ideas about the world around them. The participants shared that their guided inquiry learning experience aligned with those three components that Harlen's (2013) identified. Therefore, guided inquiry activities offer a good instructional design to use to promote adult learning. These findings lead to a conclusion that practitioners and instructors would teach adults better by incorporating independence and real-world problem-centered instruction which attract learners' interest.

5.4.3 Future Applications of Scientific Thinking

Conclusion 3: Regardless of using scientific thinking through conducting scientific experiments or tickling trial and error processes to solve problems, all participants appreciated the value of data collection and analysis and looking forward to applying knowledge learned through future experiments.

Participants who demonstrated scientific thinking also showed that they are capable of continuing to apply the same reasoning in the future. They were able to connect their reasoning process to problem solving after realizing that deductive reasoning has been an effective way to solve problems. For example, Ruby explained her idea to conduct an experiment in the future where she explained how she would use her inductive reasoning in defining her hypothesis. She already had made enough observations, where she believes factors like temperature, light, and growing medium have impact on seeds germination rate. Therefore, she looks forward to conducting an experiment, where she could use her experiment results that she generated through deductive reasoning process to compare germination rate of seeds grown outdoors and the ones germinated with hydroponics kit indoors. Leo also looks forward to doing other experiments to explore and hopefully solve problems he had in the past about gardening. For instance, he had a blossom-end rot in his tomatoes in the past. From his explanations, he used inductive and abductive reasoning talking about what would have been the cause, and he is looking forward to doing an experiment performing a comparative study to explore what might have been the cause of the problem. In the future, one of the Hope's ideas is to use her experiment results to investigate how plants respond to different length of time exposition.

One participant, who demonstrated abductive reasoning before and after the experiment, also showed intention to only apply abductive reasoning in the future. When Bella mentioned ways how she would approach her gardening problems after the end of project, her thinking implied an abductive reasoning with trial-and-error approaches. For example, she mentioned how she saw some of her vegetables were not doing well. She then removed them from the hydroponics unit and planted them outdoors in soil.

These findings suggested that deductive reasoning in which participants demonstrated through conducting experiments added a meaning to the way they solve their gardening problems. They found that experiments give them the opportunity to understand the cause and possible solutions to the problem. Also, experiments taught them the use of a systematic strategy that can be applied to understand and solve different types of problems. This conclusion aligns with Lee et al., (2004) stating that the aim of inquiry-based instruction is to instill in learners' ability to "formulate good questions, identify and collect appropriate evidence, present results systematically, analyze and interpret results, formulate conclusions, and evaluate the worth and importance of those conclusions" (Lee et al., 2004, p. 9).

5.5 Implications

The implications are pertinent to stakeholders involved in adults teaching and learning. For teaching adults scientific thinking, the findings supported the literature about how every day thinking uses inductive or/and abductive reasoning (Kenner & Klahr, 1996; Kuhn, 2010). Therefore, aiming at developing scientific thinking among adults would help them solve problems effectively using deductive reasoning through inquiry. Likewise, developing scientific thinking increase the ability of adults to appreciate valuable information, evaluate data source, and increase informed citizenry in general. As Schmaltz et al. (2017) stated, problem-solving skills stemming from scientific thinking provide people with the ability to differentiate good and valuable information from meaningless data.

Also, for teaching adults in general, instructors and instructional designers should concentrate on topics that have direct impact on adults' life, mainly focusing on real-world problem-solving. These align with Knowles adults learning theory (1980) assumptions that emphasize on learners' motivation, prior knowledge, independence and freedom of choice. Moreover, inquiry-based learning approach was used to solve problems in this study. The participants appreciated inquiry-based instructional design and enjoyed the learning experience. Guided inquiry learning also helped develop scientific thinking in adults, especially in using scientific methods and deductive reasoning process. Emphasis should be put on topics which are meaningful to them where they can utilize their prior knowledge to perform learning tasks. Likewise, even if adult learners prefer independent and freedom of choice, there is still a need for instructor to act as a facilitator of the learning process and monitor the progress of the lesson. For instance, participants were given an opportunity to conduct an experiment with a control and experimental unity. Through the instructor's facilitation, they were able to think scientifically throughout the process.

This implies that educational programs like the master gardener program, which already have an education structure, should incorporate modules that specifically intend to develop scientific thinking. Currently, the Purdue Extension Master Gardener program focuses on training volunteers in technical skills in horticultural and community outreach (Meyer, 2007). Educational programs that combine the prior knowledge of technical skills about horticulture and the reasoning process that aligns with scientific thinking would increase Master Gardener volunteers' effectiveness in solving gardening problems. In addition, to effectively train Extension Master Gardener volunteers, instructional materials should be designed to allow them independence in choosing topics of interest and focusing on real-world problems.

5.6 Limitations and Recommendations

Scientific thinking is a complex phenomenon that has been under study for decades and there are still a lot to learn about this subject. Even if much have been learned in this study, there are some recommendations for future research about scientific thinking, adults learning in general as are informed by limitations of this study.

1. The learning experience happened virtually where participants were self-regulated within a limited timeframe. An in-person approach would increase opportunities to assess participants' progress and explore more about their thinking processes. Also, instructional materials, length, structure, and tasks undertaken during the learning program were limited to the time and resources available. Future learning experience could be taught in-person where data from observations can be collected for richer descriptions of the phenomenon of interest.
2. There are different contexts like area the study took place, the topics covered, or the situation that can impact the learning process. Such contexts can impact how scientific

thinking is applied while learning. This study worked with a non-formal education program in Indiana. Future research would work with different educational programs in states other than Indiana.

3. This study used a non-formal education program with a case study of a convenient sample. The same study with a large population with a wide range of prior knowledge and background would yield more information on the factors and the extent to which those factors contribute to scientific thinking development.
4. The qualitative research approach and assessment methods detailed the participants' learning and thinking processes. However, because qualitative analysis provides a reach description of the phenomena of interest and quantitative analysis provides generalizable numerical, a mixed method would explore more deeply the understanding of scientific thinking in a larger sample of the population.

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APPENDIX A. IRB FORM

PURDUE UNIVERSITY

Date: December 20,2021
PI: HUI-HUI WANG
Re: Initial - IRB-2021-1571
Exploration Of the Indiana Master-gardener Volunteers Scientific Thinking Experiences after Participating in An Inquiry-based Home Hydroponics Project

The Purdue University Institutional Review Board has approved your study "*Exploration Of the Indiana Master-gardener Volunteers Scientific Thinking Experiences after Participating in An Inquiry-based Home Hydroponics Project*. " The study expiration date is December 17, 2024. No human subjects research may be conducted after this date without renewed IRB approval. The IRB must be notified when this study is closed. If a study closure request has not been initiated by this date, the Purdue HRPP/IRB will request study status update for the record.

Specific notes related to your study are found below.
Decision: Approved
Category:
7. Research on individual or group characteristics or behavior (including, but not limited to, research on perception, cognition, motivation, identity, language, communication, cultural beliefs or practices, and social behavior) or research employing survey, interview, oral history, focus group, program evaluation, human factors evaluation, or quality assurance methodologies.

Findings: NA
Research Notes: NA

Any modifications to the approved study must be submitted for review through Cayuse IRB. All approval letters and study documents are located within the Study Details in Cayuse IRB.

What are your responsibilities now, as you move forward with your research?

Document Retention: 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 Release Authorizations, must be maintained for six (6) years.

Site Permission: If your research is conducted at locations outside of Purdue University (such as schools, hospitals, or businesses), you must obtain written permission from all sites to recruit, consent, study, or observe participants. Generally, such permission comes in the form of a letter from the school superintendent, director, or manager. You must maintain a copy of this permission with study records.

Training: All researchers collecting or analyzing data from this study must renew training in human subjects research via the CITI Program (www.citiprogram.org) every 4 years. New personnel must complete training and be added to the protocol before beginning research with human participants or their data.

Modifications: Change to any aspect of this protocol or research personnel must be approved by the IRB before implementation, except when necessary to eliminate apparent immediate hazards to subjects or others. In such situations, the IRB should still be notified immediately.

Unanticipated Problems/Adverse Events: Unanticipated problems involving risks to subjects or others, serious adverse events, and
noncompliance with the approved protocol must be reported to the IRB immediately through an incident report. When in doubt, consult with the HRPP/IRB.

Monitoring: The HRPP reminds researchers that this study is subject to monitoring at any time by Purdue's HRPP staff, Institutional Review Board, Post Approval Monitoring team, or authorized external entities. Timely cooperation with monitoring procedures is an expectation of IRB approval.

Change of Institutions: If the PI leaves Purdue, the study must be closed or the PI must be replaced on the study or transferred to a new IRB. Studies without a Purdue University PI will be closed.

Other Approvals: This Purdue IRB approval covers only regulations related to human subjects research protections (e.g. 45 CFR 46). This determination does not constitute approval from any other Purdue campus departments, research sites, or outside agencies. The Principal Investigator and all researchers are required to affirm that the research meets all applicable local/state/ federal laws and university policies that may apply.

If you have questions about this determination or your responsibilities when conducting human subjects research on this project or any other, please do not hesitate to contact Purdue's HRPP at irb@purdue.edu or 765-494-5942. We are here to help!

Sincerely,

Purdue University Human Research Protection Program/ Institutional Review Board

APPANDEX B. INTERVIEW PROTOCOL

First Interview Protocol

1. What were the main reasons that made you join Master Gardener program?

2. What has been your experience in Master Gardener so far focusing on what you have learned.

3. How long have been a Master Gardener volunteer?

4. Tell me what you mainly do as a volunteer apart from learning?

5. How can you describe your home gardening experience if you have any?

6. What do you do first when you encounter a challenge on your garden? (challenges like disease, pest, or nutrient deficiency)?

7. Do you see yourself incorporating science into your everyday life?

8. What do you know about hydroponics

Second Interview Protocol

1. Please tell me again your hypothesis
2. Overall, how did your experiment go? (What did you measure, how often)
3. Looking back from your experiment, is there anything you can improve?
4. What inspired you to choose the topic you researched?
5. In the future, How do you think you will use (or benefit from) the information you got from this experiment or future experiments
6. Do you see the need for future experiments like this? for your personal gardening?
8. How is this experiment different from how you looked for the information before?
9. How can you describe your learning experience being both asynchronous and virtual
10. This learning experience is self-directed, you learned on your own pace, your hypothesis, etc., Please tell me how you found this experience compared to what you were used to.

APPENDIX C. WORKSHEETS

DATA COLLECTION SHEET

Hypothesis:

Variable under study:

Data collection frequency:

Hydroponics Kit A

Date	Type of Observation (what is measured)	Observation Made

Comment (any other observations):

Hydroponics Kit B

Date	Type of Observation (what is measured)	Observation Made

Comment (any other observations):

Outcome (your conclusion based on your observation):

APPENDIX D. CONSENT FORM

RESEARCH PARTICIPANT CONSENT FORM[1]

Exploration of the Indiana Master-Gardener Educators Scientific Thinking Experiences by Participating in an Inquiry-Based Homemade Hydroponics Program

Hui Hui Wang
Agricultural Sciences Education and Communication
Purdue University

Key Information

Please take time to review this information carefully. This is a research study. 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.

- This study aims at exploring Indiana Masters-Gardener volunteers' scientific thinking experiences throughout a home hydroponics Inquiry-based project. The project is designed to help educators practice scientific thinking' set of reasoning processes. Further, this study will explore and describe Indiana Master Gardener educators' experiences with both online modules and scientific thinking components. In addition, the researcher seeks to explore educators' intent to apply scientific thinking beyond the learning experience. This study will last for 5 months.

What is the purpose of this study?

- You are asked to participate in this study so that you can contribute to the knowledgeable society that operate through the use of informed decision-making process. You are also asked to participate so that you may be equipped with scientific thinking skills that would allow you to efficiently contribute to the environment friendly protection practices during your community outreach activities. We would like to enroll 10 people in this study.

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

This study's project will be an online module focusing on an inquiry-based learning using a home hydroponics system. Key components that will facilitate the learning includes fours lessons which are (1) Background and Basics about hydroponics; (2) How hydroponics meets plants needs; (3) Guided inquiry guidelines (4) Growing vegetables applying scientific thinking skills. All learning materials will be displayed using the Google classroom platform and participants are expected to spend about 20 minutes on each lesson which will be displayed in the slide format.

[1] IRB No. 2021-1571

APPENDIX E. NEED ASSESSMENT SURVEY PROTOCOL

Q1 What is your gender?

○ Male

○ Female

○ 41-50

○ >51

Q2 What is your year of birth?

○ Male

○ Female

○ Other/ Prefer not to say

Q3 What is the highest grade or level of school that you have completed?

○ Middle School (Grades 6-8)

○ Freshman (Grade 9)

○ Technical/ Associate Degree

○ Junior (Grade 11)

○ Senior (Grade 12)

Q4 Are you Spanish, Hispanic, or Latino or none of these (select all that apply).

☐ Spanish

☐ Hispanic

☐ Latino

Q5 Choose one or more races that you consider yourself to be:

- ○ White
- ○ Black or African American
- ○ American Indian or Alaska Native
- ○ Native Hawaiian or Pacific Islander

Other (specify)

Q6 Have you ever grown your own food before (Vegetables, fruits)?

- ○ Yes
- ○ No

Q7 Please tell us your desired major and minor.

- ○ Yes (Please Describe) ____
- ○ No (Please explain) ____

Q8 What is your current GPA? (4.0 Scale)

- ○ Outdoor
- ○ Indoors where you live
- ○ Both

Q9 What is your home mailing address?

- ○ Street Address Line 1
- ○ Street Address Line 2
- ○ City

Q10 What is your email address?

- ◯ Email Address
- ◯ Somewhat
- ◯ Not at all

Q11 What is your best daytime telephone number?

- ◯ Daytime Telephone Number
- ◯ Somewhat expensive
- ◯ Inexpensive

Q12 What your best evening telephone number?

- ◯ Evening Telephone Number
- ◯ Somewhat difficult to maintain
- ◯ Difficult to maintain

Q13 Which time of the year would you prefer to grow food inside your house? (Choose all that apply)

- ☐ Spring
- ☐ Summer
- ☐ Fall
- ☐ Winter

Q14 Have you ever heard of hydroponics system before?

○ Yes

○ Maybe

○ No

Q15 You are directed to this page because your answer on the previous question was "No" or "Maybe" so that you can have an idea of what Hydroponics system is. Hydroponics system is the process of growing plants in sand, gravel, or liquid, with added nutrients but without soil.

○ Done (Continue with the survey)

Q16 Have you owned or used a hydroponics food production system before?

○ Yes

○ No

Q17 How do you rate your knowledge about hydroponics? 1 Being No knowledge at all 3 Being Somewhat knowledgeable 5 Being very knowledgeable

○ 1

○ 2

○ 3

○ 4

○ 5

Q18 Choose all that apply)

- [ ] Growing area
- [ ] Lights
- [ ] Growing medium
- [ ] Type of plant
- [ ] Water quality and storage capacity
- [ ] Nutrients
- [ ] Temperature

Q19 If you were to set up a hydroponics system indoors, what factors do you think would make it hard to maintain

- ○ Growing area
- ○ Lights
- ○ Growing medium
- ○ Type of plant
- ○ Water quality and storage capacity
- ○ Nutrients
- ○ I don’t know
- ○ Temperature

Q20 If you were going to set up a hydroponics system indoors, which plants would you most likely grow?

☐ Lettuce

☐ Spinach

☐ Cucumber

☐ Others, specify ____

Q21 How interested are you in learning about Hydroponics?

○ Interested

○ Somewhat interested

○ Not interested

Q22 Do you think growing food indoors is an educational activity to do with youth or/and adults?

○ Youth

○ Adults

○ Both

Q23 Do you think growing food indoors is an enjoyable activity to do with youth or/and adults?

○ Youth

○ Adults

○ Both

Q24 Would you be interested in purchasing a pre-assembled hydroponics system?

◯ Yes

◯ Maybe

◯ No

Q25 Would you be interested in designing your own hydroponics system?

◯ Yes

◯ Maybe

◯ No

Q26 Would you be interested in acquiring appropriate (Free online access) educational resources to help you design your own hydroponics system?

◯ Yes

◯ Maybe

◯ No

Q27 Would you be interested in teaching how to grow food using hydroponics?

◯ Yes

◯ Maybe

◯ No

Q29 Would you be interested in participating in a hydroponics citizen science project (note: Citizen science is the practice of public participation and collaboration in scientific research to increase scientific knowledge) to help improve the production of home-grown crops using hydroponics?

◯ Yes

◯ Maybe

◯ No

APPENDIX F. NOTECARD

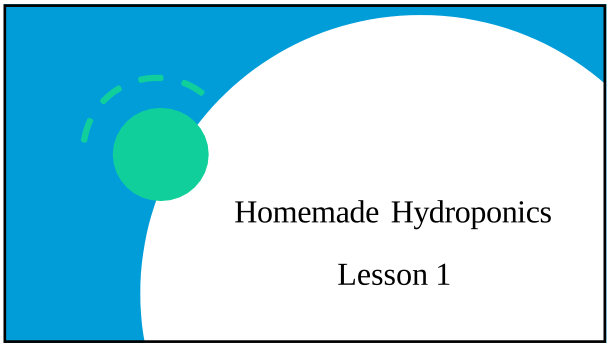
3-2-1 Notecard

3 Main Takeaways -.   -.   -.

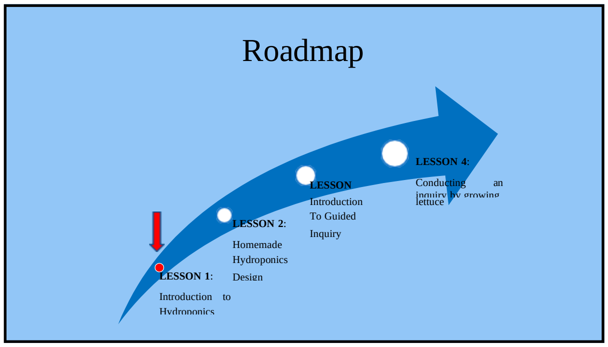
2 Things that you found interesting and that you would like to learn more about -.   -.

1 Question you still have -.

APPENDIX G. MODULE SLIDES



1



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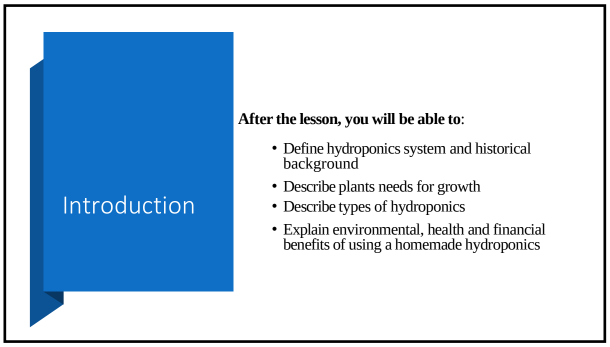
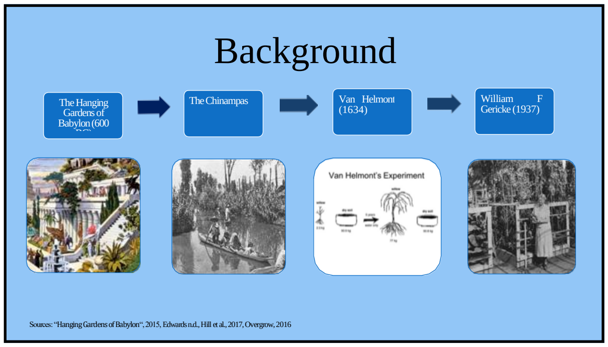


3



4

Definition

- Hydroponics can be defined as "the science of growing or the production of plants in nutrient-rich solutions or moist inert material, instead of soil".
- "The word derives from the Greek root words **"hydro"** and **"ponics,"** meaning **"water working"**.

Source: *Webster's New World College Dictionary*, fourth edition, 1999, DeJohn, 2020, p.1.

5

Plants needs for Growth

Basically, Plants need 6 components to grow:

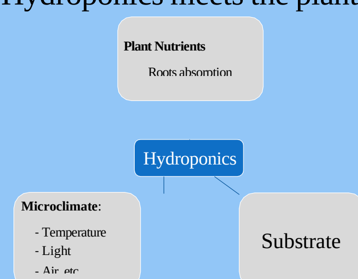
- Water
- Nutrients
- Temperature
- Light
- Air
- Structural support for the roots.

6

Water	Nutrients	Temperature	Light	Air	Roots Support
❖ Production of food ❖ Cooling the plant ❖ Absorption of some nutrients	➢ These nutrients or minerals are not actual food, but rather are elements vital to helping the plant utilize the sugars (the real food) that it produces during photosynthesis ➢ Examples And most common nutrients are N, P, K.	➢ Photosynthesis ➢ Transpiration	o Light energy is used in photosynthesis.	• Plant respiration • CO_2 for photosynthesis • Relative Humidity	Plants need a way to anchor their roots

7

How Hydroponics meets the plants needs



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Hydroponics Types

The most popular are wick system, Manual system, water culture; drip system and Nutrient Film Technique (NFT) (Resh, 1998).

- **Wick system**

This is the simplest form of hydroponics that mainly works for individual pots.

- **Water culture**

Two main types: raft or floating, and nutrient film technique.

- Nutrient film technique (NFT) is a system whereby there is no direct contact with water in the reservoir, instead watertight gullies are used to circulate nutrients solution.
- For floating technique, roots are in direct contact with water. It is suitable for growing lettuce, arugula, basil, and some herbs.

- **Aeroponics**

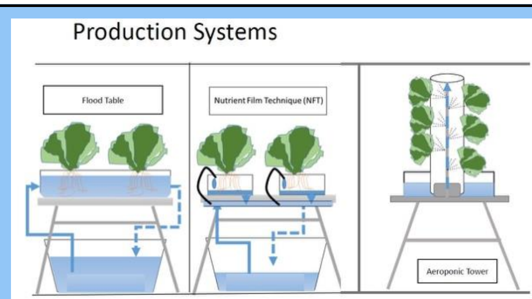
The aeroponics system uses a spinner from a home humidifier to propel nutrient solution into a polyethylene-lined plywood box atop which plants are supported on plastic light-fixture.

- **Manual system**

Simple systems operated without electricity mainly rely on slope for water flow.

9

Production Systems



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Floating Technique

Advantages

- The nutrient solution is recirculated until it is no longer usable;
- operate on a small scale and gives reasonably good plant performance with a moderate level of care.
- This is probably the simplest media-based system.

Disadvantages

- Susceptibility to root diseases
- Requirement for the periodic replacement of the rooting medium
- Inefficient use of water and nutrient reagents

https://www.urbankisaan.com/blog/hydroponic-system-designs

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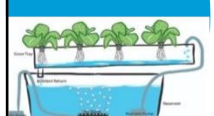
Nutrient film technique (NFT)



Advantages

- Ease of establishment
- Provides for better oxygenation of the roots;
- It is now possible to use two different irrigation systems by flowing water or various types of nutrient solutions down either channel.

Disadvantages

- Disease control can be difficult because a disease organism entering an NFT system will be quickly carried from one plant to another
- Root death is another problem in NFT installations

http://www.grotek.net/plants-growth/soil-and-soilless/

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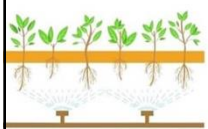
Aeroponics System

Advantages

- Very good at aeration
- Continuous exposure of the roots to a fine mist gives better results than intermittent
- The utilization of vertical space



Disadvantages

- This method is normally operated as an open system with the nutrient solution not recovered or reused.
- Difficult to ensure uniform light exposure for the

https://www.urbankisaan.com/blog/hydroponic-system-designs

13

Hydroponics Benefits

- **Environmental**
- They can be placed in urban locations close to population centers so that food does not need to travel far from harvest to market.
- They can be used in locations where quality soil is not available.
- They are free from seasonal constraints.
- They can be designed to conserve water.
- They can decrease the amount of cleaning harvested crops need before consumption.

14

Hydroponics Benefits

- **Health**
- It is relatively easy to produce healthy food with hydroponics system.
- Gardening is believed to be good physical exercise for garden owners

15

Hydroponics Benefits

- **Financial**
- They allow growers more control over nutrient availability.
- They can maximize the growth rate of plants.
- They can be designed in different sizes depending on the space available.

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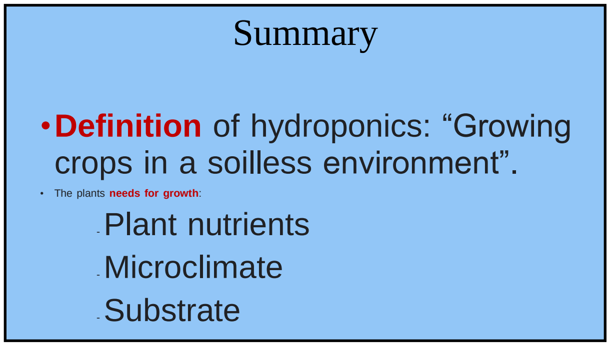
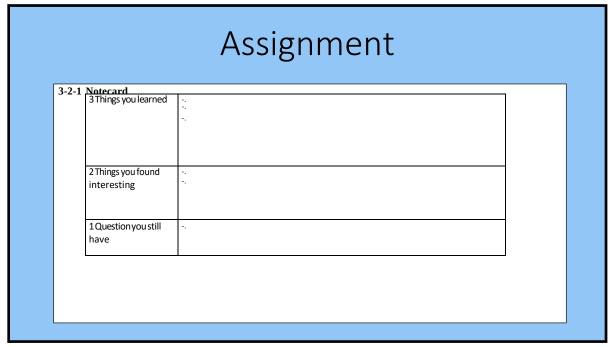
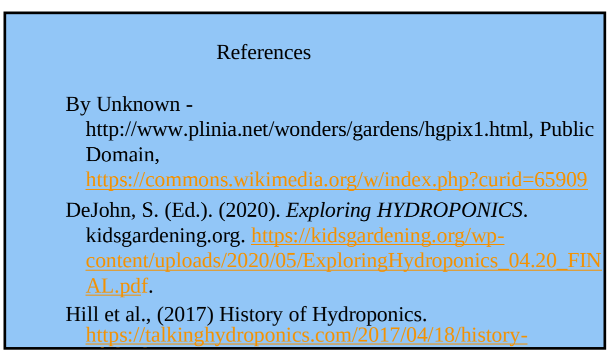

Summary
•Definition of hydroponics: "Growing crops in a soilless environment".
• The plants needs for growth:
Plant nutrients
Microclimate
Substrate

17


Assignment
3-2-1 Notecard
3 Things you learned
2 Things you found interesting
1 Question you still have

18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Thank you!!!!

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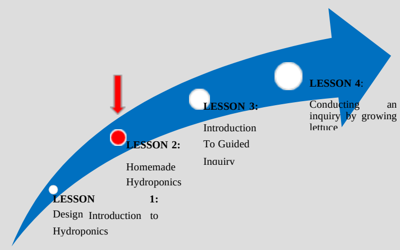
Homemade Hydroponics

Lesson 2

1

Roadmap



2

Introduction

After the lesson, you will be able to :

- Explain how a homemade hydroponics system can be designed to fulfil plants' needs
- Recognize plants nutrients deficiency symptoms and possible remedies
- Recognize regular maintenance practices

3

Hydroponics System and Plants Needs

Substrate

- Structural integrity
- Oxygenation
- Water retention
- Crop
- Sterility
- Availability
- Cost

4

Hydroponics System and Plants Needs

Water:

- Nutrient uptake
- Transport of all chemicals in and out of cells
- Photosynthesis
- Transpiration

The principle is to continually keep the amount of nutrients sufficient and accessible by the plant roots.

5

Hydroponics System and Plants Needs

Nutrients:

- **Various elements present**
- **Solubility,**
- **pH** of the soil
    - ❑ **Solubility:** amount of nutrients dissolve not just a suspension
    - ❑ **pH:** It is a measure of the acidity or alkalinity (Resh, 2015).

6

Nutrients

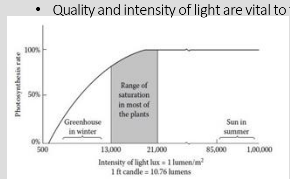
Factors that influence nutrients formulation:

- **Type of plant**
- **Stage of plant**
  growthVegetative
  stage Reproductive
  stage
- **Weathe**
  rLight
  Water

7

Light

- Quality and intensity of light are vital to the photosynthesis process



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Temperature

Crops are divided into cool-season and warm-season crops.

Cool-season crops require temperatures:

- 50s F at night
- 60s F to 70s during the day

Warm-season crops:

- 65°F or higher at night
- 75–80°F during the day.

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Solution heating impact

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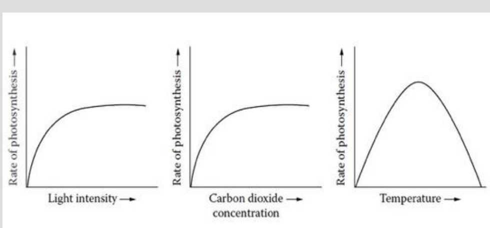
Photosynthesis activity



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Plants Nutrients deficiency symptoms

Mobile elements:

- They are: N, P, K, Mg, Zn, and Mo.
- Deficiency symptoms: Lower leaves express yellowing, browning, or spots first
- Initial symptoms will be a yellowing (chlorosis) followed by browning or drying (necrosis) of leaf tissue

12

Element	Symptoms	Remedies
N (Nitrogen)	• Lower leaves become yellowish green • Impeded growth	Add calcium nitrate or potassium nitrate to the nutrient solution
P (Phosphorous)	• Stunted growth, • Undersides of the leaves have distinct purple color • Leaves fall off prematurely.	Add monopotassium phosphate to the nutrient solution
K (Potassium)	• Scorched leaflets on older leaves • Chlorosis between veins in the leaf tissue with small dry spots. • Stunted growth.	Apply a foliar spray of 2% potassium sulfate and add potassium sulfate to the nutrient solution
Mg (Magnesium)	• Interveinal chlorosis of older leaves • necrotic spots appear.	Apply a foliar spray of 2% magnesium sulfate. Add magnesium sulfate to the solution.
Zn (Zinc)	• Abnormal small size of older leaves. • The top slow growth.	Use a foliar spray with 0.1%–0.5% solution of zinc sulfate. Add zinc sulfate to the nutrient solution.

Source: Resh,2015, p. 52-53

13

Elements	symptoms	Remedies
Ca (Calcium)	• The upper leaves show marginal yellowing progressing to leaf tips • Margins wither, and petioles curl and die back. • The growing point stops growing, and the smaller leaves turn purple-brown color on the margins	Apply a foliar spray of 1.0% calcium nitrate solution. Add calcium nitrate to the nutrient solution.
S (Sulfur)	• Upper leaves become stiff and curl down • leaves turn yellow • The stems, veins, and petioles turn purple	Add potassium sulfate or other sulfate compound to the nutrient solution
Fe (Iron)	• The terminal leaves start turning yellow at the margins and progress through the entire leaf leading eventually to necrosis. • Initially the smallest veins remain green giving a reticulate pattern. • Flowers abort and fall off	Apply a foliar spray with 0.02%–0.05% solution of iron chelate every 3–4 days. Add iron chelate to the nutrient solution.
B (Boron)	• The growing point withers and dies. • Upper leaves curl inward and are deformed (interveinal mottling) • The upper smaller leaves become very brittle and break easily.	Apply a foliar spray of 0.1%–0.25% borax solution. Add borax or boric acid to the nutrient solution.
Cu (Copper)	• Young leaves remain small • Stunted growth with "bushy" appearance of the plant at the top.	Use a foliar spray of 0.1%–0.2% solution of copper sulfate. Add copper sulfate
Mn (Manganese)	• Middle and younger leaves turn pale and develop a characteristic checkered pattern of green veins with yellowish interveinal areas • Shoots will become stunted.	Apply foliar spray of 0.1% manganese sulfate solution. Add manganese sulfate to the nutrient solution.

Source: (Resh,2015 p. 53-55)

14

16

Maintenance

- Electro-conductivity (EC)
- The sources of the plant nutrients must be highly soluble and of high purity.
- Different formulations for different stages of plant growth:
  - Starting solution
  - initial vegetative growth
  - flowering stage
  - fruit production

Summary

- Factors to consider when choosing substrate (Structural integrity, water retention, availability, etc.)
- The role water plays
- Light and Temperature roles
- Mobile vs Immobile nutrients
- Maintenance practices
  - pH
  - EC

Assignment

3-2-1 Notecard

3 Things you learned	-. -. -.
2 Things you found interesting	-. -.
1 Question you still have	-.

17

References

Nemali K. (2020) Hydroponics 101. Greenhouse and indoor production of specialty crops. Unpublished workshop presentation.

Resh, M., H. (2015). Hydroponics for the Home Growers. CRC Press

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Thank you!!!!

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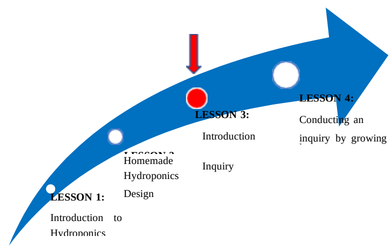
Homemade Hydroponics

Lesson 3

1

Roadmap



2

Introduction

After the lesson, you will be able to:

- Define scientific inquiry
- Describe steps and role of scientific inquiry
- Describe data and how to use data in decision making

3

Definition

- Scientific inquiry is defined as a technic used by scientists to **explain knowledge** resulting from their research whereby evidences are **systematically** collected and analyzed (NRC, 1996).
- From learners' perspective, it's defined as a way to develop understanding of science by following scientists' practices (NRC, 1996).

- curiosity
- Open to puzzlements

4

Difference between a scientific inquiry and a simple search

Inquiry is characterized by:

It is achieved by creating new knowledge, or by using data to answer a question, to support a viewpoint or to develop a solution (Alberta, 2004).

- Should mirror as closely as possible the enterprise of doing real science.
- Defending claims based on supporting evidence
- Skills and knowledge to become independent, lifelong learners

Non-Scientific Search

- It leads to knowledge gain either through readings, observation or listening, etc. which does not involve any scientific methods.
- The question of interest is answered without data analysis.

5

Guided Inquiry

- Guided inquiry learning is a scientific process ofactive exploration that uses critical, logical, and creative thinking skills to answer questions by instructor's guidance (Llewellyn, 2005).

6

Scientific Inquiry Steps

Atkin (1958), described scientific inquiry as going through eight steps.

They are:

- sensing a problem and deciding to find an answer for it
- defining the problem
- studying the situation for all factors bearing on the problem
- making the best tentative hypothesis as to the solution of the problem
- selecting the most likely hypothesis
- testing the hypothesis
- drawing a conclusion
- making inferences based on the conclusion.

7

Use of scientific inquiry findings in problem solving

- It leads to new practical knowledge
- Verification or confirmation of existing knowledge
- Inquiry findings can be used to solve a problem
- Make informed decisions

8

Types of Inquiry

Investigation Type	Purpose	Includes a Hypothesis?	Has Variables (Independent and Dependent)?	Has a Control and Experimental Group?
Descriptive	To draw conclusions	No, but does answer a question	No	No
Comparative	To determine relationships	Yes	Yes	No
Experimental	To determine a causal relationship	Yes	Yes	Yes

9

Data

- **Data** is "factual information (as measurements or statistics) used as a basis for reasoning, discussion, or calculation.“ (The Merriam-Webster Dictionary, 2005).
- Some examples can be:
  - Plant height
  - Plant color
  - Irrigation time
  - Amount and frequency of fertilizer application
  - Videos, images, artifacts, and diaries etc.

“Research data, unlike other types of information, is collected, observed, or created, for purposes of analysis to produce original research results.”

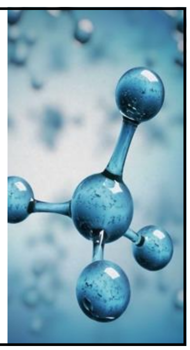
10

Role of Science and Scientific Research in General

It can be used by:

- Researchers
- Policy makers
- General Public

- ➢ Creating new knowledge
- ➢ Improving education
- ➢ Increasing the quality of our lives (UNESCO, 2021)



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Use of Data

- **Data use include:**
  - Solutions to Problems
  - Informed decisions making
  - Being Strategic (pro-active)
  - Access Resources Around You
  - Back Up Your Arguments

12

Assignment

3-2-1 Notecard

3 Things you learned	-. -. -.
2 Things you found interesting	-. -.
1 Question you still have	-.

13

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Thank you!!

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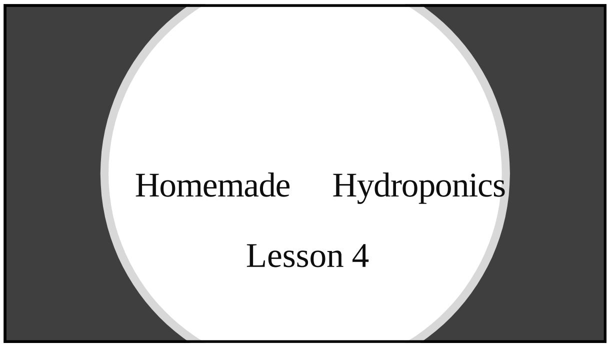
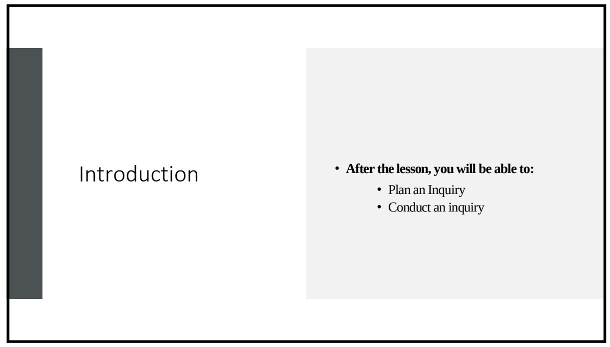
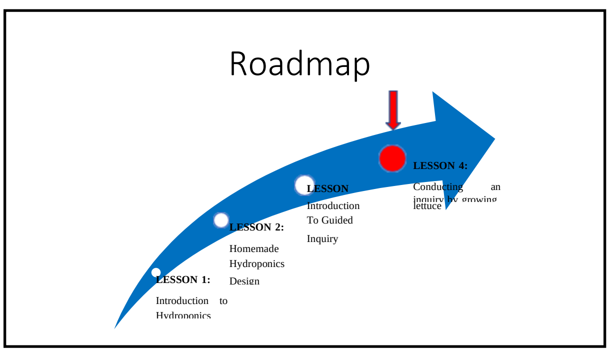

Homemade Hydroponics
Lesson 4

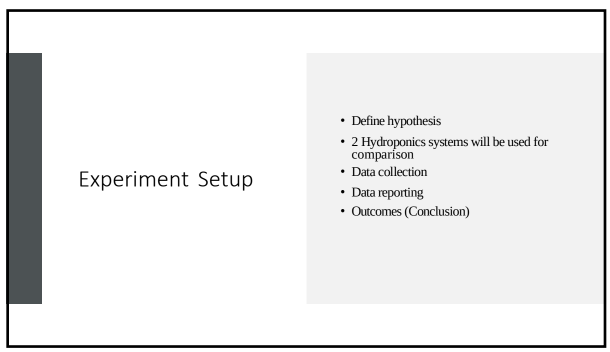
1


Introduction
After the lesson, you will be able to:
Plan an Inquiry
Conduct an inquiry

2


Roadmap
LESSON 1:
Introduction to Hydroponics
LESSON 2:
Homemade Hydroponics Design
LESSON
Introduction To Guided Inquiry
LESSON 4:
Conducting an inquiry by growing lettuce

3


Experiment Setup
Define hypothesis
2 Hydroponics systems will be used for comparison
Data collection
Data reporting
Outcomes (Conclusion)

4

Hypothesis

If the amount of crop nutrients is increased, then lettuce leaf growth will increase too.

5

Set up an experiment

6

Data Collection Sheet

DATA COLLECTION SHEET

Variable under study:

Hydroponics Kit A

Date	Type of Observation (what is measured)	Observation Made

Hydroponics Kit B

Date	Type of Observation (what is measured)	Observation Made

7

Week 1

8

Week 3

9

Week 4

10

Week 6

11

Week 8

12

Filled Form

DATA COLLECTION SHEET

Variable under study:

Hydroponics Kit A

Date	Type of Observation (what is measured)	Observation Made (Inches)
9/19/2021	Leaf length	
9/24	Leaf length	0.67
10/01	Leaf length	0.98
10/08	Leaf length	2.1
10/15	Leaf length	3.6
10/22	Leaf length	3.9
10/29	Leaf length	4.3
11/05	Leaf length	4.7
11/12	Leaf length	5.2
11/19		

Comments:

Hydroponics Kit B

Date	Type of Observation (what is measured)	Observation Made
9/19/2021	Leaf length	
9/24	Leaf length	0.67
10/01	Leaf length	1.1
10/08	Leaf length	2.4
10/15	Leaf length	3.7
10/22	Leaf length	4.4
10/29	Leaf length	4.8
11/05	Leaf length	5.6
11/12	Leaf length	5.9
11/19		

Comments:

13

Data Collection Process

- Planting date
- Type of Data
- Frequency of data collection
- Consistency

14

Conclusion

Hydroponics Kit A: ¾ o the recommended dose
Hydroponics Kit B: Recommended dose

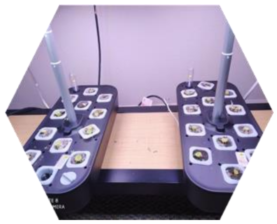
Hydroponics Kit B had a higher leaf length than Hydroponics Kit A, therefore the rate of nutrient application has an influence on plant growth (leaf length).

15

After Harvesting

16

Final Thoughts



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Assignment

3-2-1 Notecard

3 Things you learned	-. -. -.
2 Things you found interesting	-. -.
1 Question you still have	-.

18

Thank you

19