

Utah State University

DigitalCommons@USU

---

All Graduate Theses and Dissertations

Graduate Studies

---

8-2017

## Evaluating Utah 4-H STEM Curricula Used to Promote STEM in Utah 4-H Programs

Michelle D. Simmons  
*Utah State University*

Follow this and additional works at: <https://digitalcommons.usu.edu/etd>



Part of the [Agricultural Education Commons](#)

---

### Recommended Citation

Simmons, Michelle D., "Evaluating Utah 4-H STEM Curricula Used to Promote STEM in Utah 4-H Programs" (2017). *All Graduate Theses and Dissertations*. 6362.

<https://digitalcommons.usu.edu/etd/6362>

This Thesis is brought to you for free and open access by the Graduate Studies at DigitalCommons@USU. It has been accepted for inclusion in All Graduate Theses and Dissertations by an authorized administrator of DigitalCommons@USU. For more information, please contact [digitalcommons@usu.edu](mailto:digitalcommons@usu.edu).



EVALUATING UTAH 4-H STEM CURRICULA USED TO PROMOTE STEM  
IN UTAH 4-H PROGRAMS

by

Michelle D. Simmons

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

of

MASTER OF SCIENCE

in

Agricultural Extension and Education

Approved:

---

Debra Spielmaker, Ph.D.  
Major Professor

---

Dave Francis, M.S.  
Committee Member

---

Edward M. Reeve, Ph.D.  
Committee Member

---

Kelsey Hall, Ph.D.  
Committee Member

---

Mark R. McLellan, Ph.D.  
Vice President for Research and  
Dean of the School of Graduate Studies

UTAH STATE UNIVERSITY  
Logan, Utah

2017

Copyright © Michelle D. Simmons 2017

All Rights Reserved

ABSTRACT

Evaluating Utah 4-H STEM Curricula Used to Promote STEM in  
Utah 4-H Programs

by

Michelle D. Simmons, Master of Science

Utah State University, 2017

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

Evaluating curricula and resources used by extension professionals and 4-H volunteers to promote science, technology, engineering, and mathematics (STEM) in Utah is critical to keeping with the 4-H standard of excellence for promoting positive youth development. This study aimed to determine if the Utah 4-H STEM curricula used to promote STEM in 4-H programs across Utah aligned with the 4-H STEM logic model.

(118 pages)

## PUBLIC ABSTRACT

Evaluating Utah 4-H STEM Curricula Used to Promote STEM in  
Utah 4-H Programs

by

Michelle D. Simmons

Utah 4-H strives to ensure that youth receive the best that positive youth developmental programming has to offer in an endeavor to provide 4-H youth with the knowledge and skills that will give them an advantage in the workforce. The purpose of this study was to determine if Utah's Discover 4-H STEM curricula that is being used to promote STEM in Utah 4-H program met the outcomes of the National 4-H STEM logic model.

## ACKNOWLEDGMENTS

This study represents a major milestone in my career and personal life. I hold those who have gone on this graduate school journey with me in the deepest regard and am grateful for their experience and examples that has guided and shaped me along the way. Dr. Debra Spielmaker, thank you for your dedication, innovative ability to teach one concept in a hundred different ways until you found one that worked, for pushing me past every boundary I thought existed making me a better student, professional, and human being. I am eternally grateful for the high standards you set and will strive to live up to your example. I would like to thank Dr. Kelsey Hall for stepping in late in the game to help me achieve this goal, for making time to meet with me and share your knowledge and advice, and making yourself available day and night to help answer any questions I had—your dedication and passion for teaching are an inspiration. Dr. Reeve your advice and suggestions for this process have been invaluable and the courses I have taken from you have benefitted my career and the communities I serve. Dave Francis, I cannot thank you enough for your support throughout this journey, for your encouragement, words of wisdom, and calming influence. To my supervisors Troy Cooper and Kevin Kesler, the best sounding boards anyone could have, I could not have done this without your support—thank you. Kelsey Romney, I cannot thank you enough for your help during classes we shared! To my colleagues at the State 4-H Office for believing in me, thank you so much. Last and most importantly, to my loves, you are my purpose and motivation in life, without you none of this would have been possible.

Michelle D. Simmons

## CONTENTS

	Page
ABSTRACT.....	iii
PUBLIC ABSTRACT .....	iv
ACKNOWLEDGMENTS .....	v
LIST OF TABLES.....	viii
LIST OF FIGURES .....	ix
CHAPTER	
I. INTRODUCTION .....	1
Problem Statement.....	1
Purposes and Objectives .....	4
Limitation.....	5
Significance of the Study .....	5
II. REVIEW OF LITERATURE .....	7
Conceptual Framework.....	8
Origin of STEM Education.....	13
Contemporary STEM Education.....	14
Nonformal STEM Education .....	24
4-H and STEM.....	26
Curriculum Development.....	37
Curriculum Evaluation.....	39
III. METHODOLOGY .....	42
Research Design.....	42
Population and Sample .....	43
Researcher Subjectivity .....	44
Data Collection .....	45
Data Analysis.....	47

	Page
IV. RESULTS .....	50
Curricular Unit Results to Research Questions One, Two, and Three .....	51
4-H Multi-Family Club .....	51
An Unfortunate Camp .....	52
Discover 4-H Art of Math .....	54
Bugs! A Creepy, Crawly Adventure .....	55
Discover 4-H Code Clubs .....	56
Discover 4-H Forces of Nature .....	57
Fun-Damental Science Camp .....	58
Discover 4-H Geology .....	60
Discover 4-H Kitchen Science .....	60
Magician’s Laboratory .....	61
Discover 4-H Robotics .....	62
Space Explorers .....	63
Sustainable You .....	64
Overall Results .....	65
V. CONCLUSIONS AND RECOMMENDATIONS .....	74
Conclusions and Implications .....	74
Recommendations for Further Study .....	78
REFERENCES .....	84
APPENDICES .....	89
Appendix A: 4-H Science Logic Model .....	90
Appendix B: Utah 4-H Peer Review Questions .....	92
Appendix C: STEM Self-Efficacy Code Book .....	94
Appendix D: STEM Abilities Code Book .....	98
Appendix E: Bloom’s Taxonomy Action .....	103
Appendix F: 4-H Curriculum Evaluation .....	105



## LIST OF TABLES

Table	Page
1. References to STEM Self-Efficacy, STEM Abilities, and STEM Literacy in Curricular Content .....	53

## LIST OF FIGURES

Figure	Page
1. Curricular ability to provide content that could lead to STEM self-efficacy ....	67
2. Curricular ability to provide content that could lead to STEM abilities.....	68
3. Curricular ability to provide content that could lead to STEM literacy: Overall.....	69
4. Curricular ability to address the outcomes of the 4-H science logic model .....	71
5. STEM self-efficacy word cloud.....	72
6. STEM abilities word cloud.....	72
7. STEM literacy word cloud.....	73

# **CHAPTER I**

## **INTRODUCTION**

### **Problem Statement**

Since 1902, youth in 4-H have participated in projects that increase innovation and understanding of land-grant university research to local communities (4-H, 2007). 4-H is managed through Cooperative Extension—a community of more than 100 public universities across the United States that provides experiences where young people learn by doing. Through hands-on projects in health, science, agriculture and citizenship, youth are mentored by adult volunteers and who encourage them to take on proactive leadership roles. These 4-H experiences are available to youth ages 5-18, in every county and parish in the country—through in-school and after-school programs, school and community clubs and 4-H camps (4-H, 2016c).

Rising Above the Gathering Storm, a report published in 2006, warned that Americans may not know enough about science, technology, or mathematics to significantly contribute to, or fully benefit from, the knowledge-based society that is already taking shape around us (Locklear, 2013). In 2007 4-H recognized that it was at a pivotal moment in which the opportunity to reaffirm itself as a leader in nonformal science, engineering, and technology education had been presented (4-H, 2007). In response, the National 4-H Science Initiative presented a way to focus 4-H programming on teaching science, technology, engineering, and applied math content (Mielke, LaFleur, Butler, & Sanzone, 2013). The goal of the 4-H Science Initiative is to increase science

interest and literacy among youth, increase the number of youth pursuing post-secondary education in science, and increase the number of youth pursuing science careers (Mielke, et al., 2013). In 2013 the National 4-H organization reported more than one million youth were engaged in 4-H led science programs (Locklear, 2013).

Utah 4-H has supported the National 4-H effort to increase science interest and literacy among youth by creating opportunities for youth to participate in science, technology, engineering, and math (STEM) programs. These programs are intended to provide “activities and curriculum [to] introduce youth to science, technology, engineering and math in an engaging, hands-on learning environment” (Utah 4-H, 2016a).

Several curricula and resources developed nationally and within Utah are used to provide STEM programming statewide. A national 4-H Science Checklist has been developed to assess if 4-H science programs and associated curriculum are science ready. However, resources used in Utah 4-H STEM programs have never been formally examined to assess the validity of the curricula or the programming related to national 4-H Science Checklist. In 2011, the Successful STEM Education Organization published a brief about the need to improve STEM curriculum and instruction and found that

Many factors affect student learning, including school culture to teacher ability to parent support. U.S. schools are trying new ways to improve math and science education by focusing on a variety of these areas. But at the core of the efforts are the age-old questions of what to teach and how to teach it—curriculum and instruction. To many, the answer is clear: the curriculum must be focused, rigorous, and coherent. (National Research Council, 2011, para 4, para 4)

The goal for 4-H STEM programming nationally is to move beyond offering activities to providing youth with ongoing, sequential programming that leads to mastery

(4-H Science Program Design, 2013). The National 4-H Science Logic Model (see Appendix A) illustrates that youth who participate in 4-H STEM programs should experience an increase in STEM self-efficacy, STEM abilities, and STEM literacy. According to the 4-H Science Logic Model, STEM self-efficacy is demonstrated through increased engagement in STEM, improved attitudes towards STEM, is applied through life skills, and express interest in STEM careers. The 4-H Science Logic Model also illustrates STEM abilities as improved science skills and knowledge, application of STEM learning outside of 4-H (e.g., school classes, science fairs, etc.), and adoption and utilization of new methods and improved technology. The 4-H Science Logic model further concludes that increased awareness of science and an increased awareness of opportunities to use science to contribute to society are an indication of youth STEM literacy (4-H Science Logic Model, 2010).

To achieve the outcomes of the Logic Model and meet the requirements of the 4-H checklist, the outputs (4-H science curricula) need to be valid. The development of valid STEM curricula is crucial as it affects the quality of STEM programming received by 4-H youth. STEM education combines rigorous academic concepts with real-life lessons as students apply science, technology, engineering, and mathematics in settings that connect school, community, work, and the global economy, this approach builds STEM self-efficacy, STEM abilities, and STEM literacy among youth providing them with a competitive edge in today's workforce (Gerlach, 2012). Therefore, STEM curricula should follow the three-dimensional approach illustrated in a model developed by the National Research Council and adopted in the Next Generation Science Standards

that strategically combines disciplinary core ideas (e.g., life science, engineering, etc.), cross cutting concepts (e.g., patterns, energy and matter, etc.), and science and engineering practices (e.g., developing and using models, analyzing and interpreting data, etc.; Houseal, 2015) As STEM curricula follows the three-dimensional approach, youth are more likely experience an increase in STEM self-efficacy, STEM abilities, and STEM literacy.

Acknowledging that STEM curriculum must be “focused, rigorous, and coherent” (National Research Council, 2011, para 4) in order to be effective, the lack of a formal evaluation process in regards to Utah 4-H STEM curricula is concerning. In other words, Utah 4-H youth may not be participating in valid STEM programming to achieve the 4-H Science Logic Model outcomes.

This research sought to determine if Utah 4-H materials are supporting “Science Ready” and STEM readiness goals (STEM self-efficacy, STEM abilities, and STEM literacy). For the purpose of evaluation, this research utilized the Theory of Change conceptual framework to determine if the curricula met STEM readiness goals by examining STEM curricula developed by Utah 4-H for STEM programming. This approach attempted to determine the curricula’s validity in meeting the criteria for STEM education.

### **Purposes and Objectives**

The purpose of this study was to analyze STEM curricula used by Utah 4-H leaders for STEM education to determine if and to what extent the curricula addresses

STEM concepts to increase youth self-efficacy, youth STEM abilities, and STEM literacy leading to improved opportunities for youth to pursue STEM-related careers. An examination of methods used to evaluate 4-H STEM curricula for educational requirements provided a research based process for reviewing and selecting 4-H STEM curricula.

### **Objectives**

1. To determine if 4-H STEM curricula addresses 4-H STEM Logic Model
2. Based on findings of this study make recommendations for a research-based rubric and template to be used in 4-H STEM curricula development.

### **Research Questions**

1. Does Utah 4-H STEM curricula provide activities that could lead to increased youth STEM self-efficacy?
2. Does Utah 4-H STEM curricula provide content that could lead to STEM abilities?
3. Does Utah 4-H STEM curricula provide content related to STEM literacy?

### **Limitation**

State 4-H leaders may be using STEM curricula outside of the Utah 4-H STEM curricula identified to be examined by the study. The lack on an intercoder-reliability score is also a limitation of the study, however, experts helped to frame the coding scheme and data analysis for consistency.

### **Significance of the Study**

Valid curricula are critical to delivering successful STEM programming in Utah and in 4-H programs nationally. STEM camp guides and Discover 4-H Clubs curricula available through the Utah 4-H website are resources used by 4-H staff and volunteer leaders to deliver STEM programming (personal communication, Dave Francis, December 12, 2016) to youth grades 3-12. Currently in Utah, the 4-H curricula are reviewed on 13 criteria (Appendix B, but none of the items addresses the STEM constructs. To date no formal evaluation has been conducted to examine Utah 4-H curricula as a valid resource that would increase 4-H member self-efficacy, STEM abilities, or STEM literacy. With no formal evaluation, there is a concern that 4-H STEM programming in Utah may not be delivering valid STEM education meeting the 4-H STEM outcomes as identified by the 4-H STEM Logic Model. Findings from this study will determine if 4-H STEM curricula used to deliver STEM programming in Utah are valid STEM resources.



## **CHAPTER II**

### **REVIEW OF LITERATURE**

Unlike nationally supported 4-H STEM curriculum, the peer review process used to evaluate STEM curricula developed by Utah 4-H Extension professionals does not require an evaluation of the content presented and is not necessarily reviewed by individuals who have an understanding of STEM concepts (personal communication, Dave Francis, December 2016) Because very little STEM curricula and resources exist for out-of-school or nonformal science programs, Utah 4-H staff have developed their own STEM curricula to provide an easy way to incorporate STEM into 4-H camps and clubs (Utah 4-H, 2016b). However, a formal evaluation of these curricula has not been conducted to determine if these resources meet the criteria for STEM curricula. Reviewing previous studies that focused on STEM education, successful out-of-school and nonformal STEM programs, and evaluations of STEM curricula will aid in clarifying the standards for valid STEM curricula.

Providing a clear definition of what successful STEM education entails was a primary dependent variable throughout the literature reviewed. The focus across the studies reviewed was to identify characteristics of successful STEM programs, including nonformal out-of-school settings such as 4-H, and evaluating STEM programs and STEM curricula each resulting in a consistent definition of STEM education.

This systematic review of literature included articles that met the following criteria: (a) presented a clear definition and characteristics of STEM education, (b) identified successful out-of-school setting STEM programs, and (c) had been evaluated as

STEM curriculum. Articles published between 2006 and 2016 were included for their relevance to the research topic for their ability to more closely reflect current STEM literature.

### **Conceptual Framework**

Based on outcomes of the 4-H Science/STEM Logic Model, STEM self-efficacy, STEM abilities, and STEM literacy are increased when youth participate in 4-H STEM programs. Sources for STEM self-efficacy, STEM abilities, and STEM literacy are introduced through activities that focus on real-world issues, follow the engineering design process, engage youth hands-on inquiry and open-ended questioning, opportunities to learn to work as a productive team, apply rigorous math and science content, and allow for numerous correct responses and reframe failure as a necessary part of learning (A. Jolly, 2014, p. 1). These constructs will be measured in the analysis of 4-H curricula to achieve the desired outcomes. Defining each of the three constructs and the sources in which they are acquired provides clarity as they relate to the development of valid STEM curricula.

Defined, self-efficacy is a person's "beliefs about their capabilities to produce designated levels of performance that exercise influence over events that affect their lives. Self-efficacy beliefs determine how people feel, think, motivate themselves and behave" (Bandura, 1994, p. 71). Researchers with the Assessing Men and Women in Engineering Project found that "self-efficacy is goal directed—self-efficacy assessments direct respondents to rate their level of confidence for attaining a specific goal, it

influences the choices individuals make in term of goal choice, the effort expended to reach those goals, and persistence when difficulties arise” (Rittmayer & Beier, 2008, p. 1).

The 4-H Science Logic Model illustrates that STEM self-efficacy is built through experience based learning activities as youth to work together to reach a goal and is observed as youth demonstrate an increased engagement in STEM, improve attitudes towards STEM, is applied through life skills, and express interest in STEM careers (4-H Science Logic Model, 2010). STEM curricula promote STEM self-efficacy by engaging youth in hands-on inquiry challenges, providing youth with opportunities to learn to work as a productive team to solve a problem, allowing for numerous correct responses, and reframing failure as a necessary part of learning. Within STEM curricula, inquiry based tasks/activities terms such as work together to prepare, analyze, apply, build, monitor, and communicate findings on a real-world issue will be attributed to the mastery experiences that promote STEM self-efficacy.

The U.S. Department of Education defined STEM abilities as “the knowledge and skills to solve tough problems, gather and evaluate evidence, and make sense of information as these are the types of skills that students learn by studying science, technology, engineering, and math—subjects collectively known as STEM (U.S. Department of Education, n.d., para 1). The *K-12 Framework* and the NGSS, in conjunction with College Board, agree that “knowledge of the overarching ideas in the science disciplines (i.e., earth and space science, life science, physical science, and engineering) and how the practices of science are situated within this content” reflect the

STEM abilities youth require to cultivate and master to be ready for college and 21st-century careers (NGSS Lead States, 2013, p. 376). The 4-H Science Logic Model reports that STEM abilities are demonstrated as youth improve science skills and knowledge, apply STEM learning outside of 4-H (e.g., school classes, science fairs, etc.), and adopt and utilize new methods and improved technology which may lead to future interest in post-secondary STEM degrees and STEM careers. STEM curricula that present activities that follow the engineering design process and build youth abilities to apply rigorous math and science content to solve challenges are sources that promote STEM abilities. Within STEM curricula, inquiry based tasks/activities terms such as plan, design, test, prepare, build, and redesign will be attributed to sources that promote STEM abilities.

Another goal of STEM education is to increase STEM literacy—defined as the knowledge and understanding of scientific and mathematical concepts and processes required for personal decision making, participation in civic and cultural affairs, and economic productivity for all students” (National Research Council, 2011, p. 12).

According to You for Youth, an online community for afterschool professionals,

Science literacy is defined as the ability to use knowledge in the sciences to understand the natural world. Technological literacy is the ability to use new technologies to express ideas, understand how technologies are developed, and analyze how they affect us. Engineering literacy is the ability to put scientific and mathematical principles to practical use, and mathematical literacy is the ability to analyze and communicate ideas effectively by posing, formulating, solving and interpreting solutions to mathematical problems. (STEM Literacy, n.d., para 1)

In a five-step paradigm introduced in a study that explored pedagogical methods for promoting STEM literacy researchers suggested that STEM literacy, would increase if learning methods:

1. Expose students to engineering concepts through projects using audio/visual media (i.e. internet, books, media).

2. Didactically lecture students about engineering/science/engineering theory through real-life applied problem-based learning.
3. Assign students an abstract, socially and culturally relevant group-based project requiring students to utilize knowledge attained from the previous steps (lecture and research).
4. Students group presentations focusing on: a) why the project was developed, the need for the project, b) how does the design engineer a solution to the presented problem, c) what is the underlying theory as to how the model works (mathematical/scientific), & d) what methodology was used to make the design.
5. Students are academically tested for theoretical concepts, resolving problem-based concepts and engineering design through examination (Persaud-Sharma, 2013).

STEM curricula increases STEM literacy when making connections to content by posing open-ended questions that encourage youth to identify other real-world issues related to earth, space science, life science, and physical science and how technology, engineering, and mathematics can be used to create solutions. Within STEM curricula, phrases and terms such as demonstrate, theorize, utilize knowledge attained, who, what, when, where, why, and how will be attributed to sources that promote STEM literacy.

The 4-H Science Logic Model (2010) concluded that as a result of STEM programming an increased awareness of science and an increased awareness of opportunities to use science to contribute to society were indicators of youth STEM literacy. These definitions of STEM self-efficacy, STEM abilities, and STEM literacy further imply that the STEM curricula developed by Utah 4-H should be formally evaluated.

STEM literacy is vital in providing youth with the quality programming the 4-H organization has been recognized for its ability to contribute to the development of youth

life skills such as self-esteem, self-motivation, and resiliency (Hendricks, 1998) are significant predictors of both “the level of motivation for a task and ultimately task performance; on average, individuals with high STEM self-efficacy perform better and persist longer in STEM disciplines relative to those lower in STEM self-efficacy” (Rittmayer & Beier, 2008, p 1).

Logic models have an association with the theory of change (TOC). TOC is a tool for “developing solutions to complex social problems which explains how a group of early and intermediate accomplishments sets the stage for producing long-range results” (A. Anderson, 2005, para 3). Logic models have an association with the TOC; therefore, using the TOC Logic Model as the conceptual framework affords the ability to measure if the 4-H Science/STEM Logic Model outcomes can be related to curricula outputs, STEM self-efficacy, STEM abilities, and STEM literacy. These outputs address the goals for K-12 STEM education in the United States capturing the focus of STEM education and reflecting the types of intellectual capital needed for growth and development in an increasingly science- and technology driven world (National Research Council, 2011).

Theory of Change is essentially a comprehensive description and illustration of how and why a desired change is expected to happen in a particular context. It is focused in particular on mapping out or ‘filling in’ what has been described as the ‘missing middle’ between what a program or change initiative does (its activities or interventions) and how these lead to desired goals being achieved. (Center for Theory of Change, 2016)

Curriculum is an example of an input in a TOC model, as it is believed that students receiving the curriculum will apply the learned concepts resulting in the desired outcome and change.

## Origin of STEM Education

In contemporary STEM Education, Judith A. Ramaley, the former director of the National Science Foundation's Education and Human Resources Division, has been attributed with outlining the science, technology, engineering, and mathematics curriculum (Koonce, Zhou, Anderson, Hening, & Conley, 2011). While Ramaley's contribution to contemporary STEM education is paramount, "America has had a long-standing involvement with STEM issues that dates back to the establishment of West Point in 1802" (J. L. Jolly, 2009, p. 50). Historically, STEM concepts were not the focus in traditional educational settings but were utilized in many aspects of the business world such as engineering practices to produce innovative technologies (e.g., light bulb, automobiles, tools and machines; White, 2014). The Morrill Act of 1862, initially proposed to establish the study of agriculture and mechanical arts, supported science and engineering programs as well. This Act ultimately resulted in the creation of the university research system (J. L. Jolly, 2009).

"Parallels can be drawn between STEM initiatives involving the launch of the Soviet Satellite Sputnik in 1957, its legislative history, and the current 'quiet crisis' over America's ability to compete globally" (J. L. Jolly, 2009, p. 50). A groundbreaking technical achievement

Sputnik caught the world's attention and the American public off-guard and also garnered swift action from the U.S. federal government. The United States reaction to the launch of Sputnik set the stage for an unprecedented infusion of funding from the federal government to reform public education at all levels.... Fast-forward 50 years and the United States finds itself in an analogous situation. Rather than competing with one rival, such as the Soviet Union, the United States is operating in a global marketplace. (Jolly, 2009, pp. 50, 52).

## Contemporary STEM Education

*STEM 2026: A Vision for Innovation in STEM Education*, a report issued by the U.S. Department of Education Office of Innovation and Improvement, reiterated that STEM is a vital element needed to provide students with a well-rounded education (U.S. Department of Education, Office of Innovation and Improvement, 2016). Researchers concluded that in addition to science, social studies, literature, the arts, physical education and health, and opportunities to learn foreign languages, “the process of learning and practicing the STEM disciplines can instill in students a passion for inquiry and discovery and fosters skills such as persistence, teamwork, and the application of gained knowledge to new situations” (U.S. Department of Education, Office of Innovation and Improvement, 2016, p. 1).

Professionals argue that one’s academic persistence and dedication to continued learning in today’s rapidly evolving world is directly related to the types of growth mindsets and habits gained through participation in STEM education (U.S. Department of Education, Office of Innovation and Improvement, 2016). The STEM 2026 report defined solid STEM education as one that builds the abilities and beliefs described above, sets the path for a lifetime of learning beginning in early childhood, is socially receptive, utilizes problem and inquiry-based learning models, and involves students in hands-on activities that provide opportunities to interact with leaders with careers in STEM professions (U.S. Department of Education, Office of Innovation and Improvement, 2016).

Formal and nonformal educators alike understand that providing successful



STEM educational programs is critical to developing STEM literate youth who will possess the skills to pursue advanced STEM degrees and prepared to serve in various capacities throughout the workforce. Numerous studies on STEM education have focused on identifying what characteristics are needed in order to implement a successful STEM program.

Research related to STEM education revealed the combination of core concepts and skills being taught within their specific subjects but sharing a common theme in the introduction of closely linked concepts and skills from two or more disciplines with the intention of “deepening understanding and skills; the implementation of a transdisciplinary approach, where knowledge and skills from two or more disciplines are applied to real-world problems and projects with the goal of shaping the total learning experience” (English, 2016, p. 1).

“On its surface, ‘STEM’ is the acronym of science, technology, engineering, and mathematics. However, when you pull that first layer away, you reveal the most elaborate puzzle in the education world” (Gerlach, 2012). STEM education is more than just a grouping of subject areas and activities, “it is a movement to develop the deep mathematical and scientific underpinnings students need to be competitive in the 21st-century workforce (A. Jolly, 2014). STEM education was created to intentionally combine existing curriculum for the purpose of equipping youth with the ability to think critically and rationally, work in a group setting, analyze data, and to identify and create solutions to real world problems. It is a movement to develop the deep mathematical and scientific understanding that students need to be competitive in the 21<sup>st</sup>-century

workforce (A. Jolly, 2014). *STEM: Defying a Simple Definition*, a report issued by the National Science Teachers Association, defined by Nancy Tsupros, STEM education is

An interdisciplinary approach to learning where rigorous academic concepts are coupled with real-world lessons as students apply science, technology, engineering, and mathematics in contexts that make connections between school, community, work, and the global enterprise enabling the development of STEM literacy and with it the ability to compete in the new economy. (as cited in Gerlach, 2012, para 2)

Despite the increased attention to STEM in policy and funding arenas, there remains some confusion about STEM, the individual subjects, the combination of the subjects, and even what constitutes STEM (National Research Council, 2014). While numerous definitions and examples of STEM education and learning exist, previous studies agreed that valid STEM curricula focuses on real-world issues, presents challenges that follows the engineering design process, engages youth in not only hands-on inquiry but open-ended questioning, provides youth with opportunities to learn to work as a productive team, requires the application of rigorous science, technology, engineering, and mathematic content, allows for numerous correct responses and reframes failure as a necessary part of learning which are sources of the constructs being measured by this study as they have been shown to increase youth STEM self-efficacy, STEM abilities, and STEM literacy. Therefore, offering a clear and consistent definition of STEM education across the policy making, funding organizations, formal educational settings and nonformal (out-of-school time) settings such as 4-H is fundamental to building a successful STEM learning system.

When the combination of STEM subjects was first introduced as an educational concept two issues were the primary focus.

First, there was (and still is) a growing concern that the United States was not preparing a sufficient number of students, teachers, and practitioners in the STEM fields. Second, our industries needed more workers in these fields due to an aging workforce and an increasingly innovative world market. (Gerlach, 2012, para 4)

According to the U.S. Department of Education (2015):

The United States has developed as a global leader, in large part, through the genius and hard work of its scientists, engineers, and innovators. In a world that's becoming increasingly complex, where success is driven not only by *what* you know, but by what you *can do* with what you know, it's more important than ever for our youth to be equipped with the knowledge and skills to solve tough problems, gather and evaluate evidence, and make sense of information. (U.S. Department of Education, 2015, para 1)

The U. S. Department of Commerce reported that workers in the STEM fields are vital to propel America into the future and provide them with a competitive advantage by creating innovative ideas, new enterprises and new business ventures. The concern among U.S. businesses is the lack of employees with STEM abilities. Since 2001 job growth in the STEM field has tripled over that of non-STEM jobs with STEM workers experiencing less joblessness than those in employed in non-STEM careers. The continued growth and strength of the U.S. economy will rely on individuals who are trained for careers in the STEM field that will propel the United States into the future (Langdon, McKittrick, Beede, Khan, & Doms, 2011).

The need to consistently evaluate and seek to improve STEM learning in formal educational settings and out-of-school settings such as 4-H is reflected in the increasing number of programs. It has also been noted that there are STEM jobs at all levels not just for professional scientists that require knowledge of STEM (National Research Council, 2011). Research in STEM learning over the last two decades allowed the Committee on Highly Successful Schools the opportunity to illustrate effective STEM education as

follows, “effective instruction capitalizes on students’ early interest and experiences, identifies and builds on what they know, and provides them with experiences to engage them in the practices of science and sustain their interest” (National Research Council, 2011, p. 19). Yet the same study found that among formal educators, professional development in STEM education when available is often short, fragmented, ineffective, and not designed to meet the specific needs of individual teachers (National Research Council, 2011) and applies to volunteer development training among those who facilitate STEM programs in out-of-school time programs as well. This serious disconnect between “knowledge” and “understanding” of STEM concepts is reflected as many educators know what STEM stands for, but do not fully comprehend its meaning (Gerlach, 2012) which diminishes their ability to effectively teach STEM concepts and directly affects the probability of youth developing an ability to effectively apply STEM skills in real world settings.

A study conducted by the National Academy of Science (NAS) aimed at identifying effective approaches to STEM education in the U.S. outlined three broad goals to build STEM skills among the nation’s youth must first, expand the number of students who ultimately pursue advanced degrees and careers in STEM fields and broaden the participation of women and minorities in those fields. Second, expand the STEM-capable workforce and broaden the participation of women and minorities in that workforce. Finally, increase STEM literacy, which is the student's ability to understand and apply concepts from science, technology, engineering and mathematics in order to solve complex problems (You For Youth [Y4Y], n.d.), for all students, including those

who do not pursue STEM-related careers or additional study in the STEM disciplines (National Research Council, 2011). The study also explored the following three types of criteria for identifying successful STEM programs.

The first criteria identified was student STEM outcomes as student and school-level achievement test data are the most widely available measures and the measures used for accountability purposes, therefore they are the measures most commonly used to gauge success, regardless of the goals of a particular school or program (National Research Council, 2011). While many out-of-school time programs do not consistently collect test data to measure achievement 4-H depends on evaluations of state-and county-level implementation and delivery of science programming to measure youth engagement in science, attitudes towards science, and knowledge of science; and promising practices used in science programs (Mielke, LaFluer, Butler, & Sanzone, 2013). Similar to formal educational institutions, periodic evaluations at national, state, and local levels of 4-H STEM programs should be conducted to determine if they are developing STEM capable youth and measure STEM skills gained as a result of their participation in 4-H STEM programming.

The second criteria identified was STEM-focused school types such as selective STEM schools that enroll relatively small numbers of highly talented and motivated students with a demonstrated interest in and aptitude for STEM, inclusive STEM schools that “emphasize or are organized around one or more of the STEM disciplines but have no selective admissions criteria and provide experiences similar to that of selective schools but serve a broader population,” and finally schools with STEM-focused career

and technical education (CTE) that seek to prepare the next generation of scientists and innovators, expanding the number of capable students for the STEM workforce, increasing science literacy for all, and generally preparing students for postsecondary success (National Research Council, 2011, p. 6). 4-H STEM-focused programming, similar to inclusive STEM schools, is dedicated to providing youth from diverse backgrounds, with a special interest in attracting female and minority youth, with fun, hands-on learning opportunities intended to help them evolve a deeper understanding of agricultural science, electricity, mechanics, entrepreneurship, and natural sciences, as well as rocketry, robotics, bio-fuels, renewable energy, computer science, and environmental sciences to name a few (4-H, 2016b).

The third criteria focused on effective STEM instruction and program practices as indicators of successful STEM education. In a description that is consistent with the three goals for U.S. STEM education outlined above, effective STEM instruction capitalizes on students' early interest and experiences, identifies and builds on what they know, and provides them with experiences to engage them in the practices of science and sustain their interest. (National Research Council, 2011). According to the research conducted by the National Academy of Science effective STEM instruction,

Actively engages students in science mathematics, and engineering practices throughout their schooling. Effective teachers use what they know about students' understanding to help students apply these practices. In this way, students successively deepen their understanding both of core ideas in the STEM fields and of concepts that are shared across areas of science, mathematics and engineering. Students also engage with fundamental questions about the material and natural worlds and gain experience in the ways in which scientists have investigated and found answers to those questions. In grades K-12, students carry out scientific investigations and engineering design projects related to core ideas in the disciplines, so that by the end of their secondary schooling they have

become deeply familiar with core ideas in STEM and have had a chance to develop their own identity as STEM learners through the practices of science, mathematics, and engineering. (National Research Council, 2011, p. 19)

Much like STEM-focused schools, 4-H curriculum, projects, and clubs are designed according the experiential based learning model, which provide youth with an activity, an opportunity to look back at it critically, and determines what was useful or important to remember, then moves to self-mastery as youth use what they have learned to perform another activity. This brand of instruction remains the exception in U.S. schools yet it is typically facilitated by extraordinary teachers who overcome a variety of challenges that stand between vision and reality (National Research Council, 2011).

While the effective practices for STEM mirror general educational practices the research conducted by the NAS aimed at identifying effective approaches to STEM education suggest that some strategies are unique to STEM learning and some challenges particularly affect success in STEM (National Research Council, 2011).

Drawing on those findings the NAS proposed a series of steps that need to be taken at local, state, and national levels to improve STEM education. First, educational policy makers should consider all models of STEM focused schools and choose the practices that support effective STEM learning (National Research Council, 2011). This approach should be examined by out-of-school time programs such as 4-H as these schools are running successful STEM programs in which provides an accessible resource for adapting practices to afterschool STEM programming that compliments what youth are being introduced to in school.

Second, organizations should devote ample instructional time and resources to

science in grades K-5 as early immersion is a foundation that stimulates students' continued interest in science in middle and high school, as well as increasing the possibility that youth will pursue STEM careers (National Research Council, 2011). One noticeable issue with 4-H produced STEM curriculum is the lack of curricula for Cloverbuds (4-H youth 5-7 years of age). The existing curriculum is intended to serve traditional 4-H youth who range in ages from 8-18 and cover grades 3-12 which is too broad when considering age appropriate content and activities. Introductory 4-H STEM programs for grades K-2 would enhance learning for youth within these nonformal educational settings. These beginner 4-H programs could be created by examining core curriculum in science, mathematics, and engineering and adapting them to existing 4-H project areas such as sewing construction and kitchen science as STEM preparation curricula.

Third, organizations should ensure that STEM curricula focuses on key topics in the disciplines separately, are challenging, and are articulated as a sequence of topics and performances (National Research Council, 2011). Developing meaningful 4-H STEM curricula that provides age and grade level appropriate science, mathematics, and engineering concepts that reflect core curriculum standards would provide a structured framework across nonformal educational settings and increase STEM learning and STEM skills among youth who participate in both in school and out-of-school STEM programs.

The final two suggestions propose that STEM educational programs must build the capacity of its program facilitators to ensure a deep knowledge of the subject matter and a thorough understanding of how students' learn while creating an environment that



supports student's achievement (National Research Council, 2011) Formal educators are trained how to teach youth in a specific discipline and are required to attend yearly professional development trainings which reinforce and introduce current educational approaches to learning. Unlike formal educators, 4-H volunteers are not required to have an educational background or formal training in the project areas in which they serve. This means that 4-H STEM curricula, at the very least, needs to include the necessary background for 4-H volunteers to be successful with their STEM club endeavors.

While 4-H volunteer development trainings that focus on ages and stages of learning and project specific volunteer training workshops exist, they not required. Therefore, 4-H volunteers who have no background in STEM rely on 4-H STEM curricula to learn STEM concepts before introducing them to youth. If 4-H curricula produced on the national level as well as Utah 4-H STEM curricula and resources do not contain easily identifiable STEM concepts, untrained program facilitators may struggle to identify the core concepts embedded in STEM lessons creating a barrier to effective STEM learning.

Productive out-of-school STEM programs (like 4-H) need to meet three criteria by first engaging young people intellectually, academically, socially, and emotionally. In addition, these programs must respond to the interests, experiences, and cultural practices of the youth who participate. Furthermore, these programs must connect STEM learning, not only in their out-of-school settings, but school, home, and other settings as well (National Research Council, 2015).

## **Nonformal STEM Education**

Many organizations have begun including STEM to the learning opportunities offered in out-of-school programs in recent years. For example, an increasing number of youth development organizations such as 4-H, the Boy Scouts and Girl Scouts, and Boys and Girls Clubs have embraced STEM as an important strategy for supporting youth in the intellectual, social, and emotional development (National Research Council, 2015). 4-H programs are designed to meet the social and emotional needs of youth participants by engaging them through their interests and experiences which addresses their intellectual and academic needs as well. 4-H programs in science, healthy living and citizenship are backed by a network of 100 public universities and a robust community of 4-H volunteers and professionals. Through hands-on learning, kids build not only confidence, creativity and curiosity, but also life skills such as leadership and resiliency to help them thrive today and tomorrow (4-H, 2016d). Yet research has raised questions about the quality of STEM learning experiences in existing programs. In a study of out-of-school programs in California researchers found that while most programs included STEM activities, only a small proportion provide opportunities for youths to participate in inquiry-based STEM learning (National Research Council, 2015).

For example, based on the NAS definition of STEM instruction, placing a raisin in a carbonated beverage and watching it float and sink is not a STEM lesson nor is it a STEM activity unless STEM concepts such as those defined in Archimedes Principle (volume, density, buoyancy, etc.) are discussed and youth are presented with a question to answer and are given the opportunity to provide a solution and an expectation to reflect

upon the process and then apply what they have learned in a real world setting. Another concern with out-of-school time STEM programming is that these settings host multiple grade levels simultaneously. Using the above STEM activity as an example, Utah youth learn about volume and density in the seventh-grade according to the Utah Education Network, which would make the activity inappropriate for youth in grades that have not been introduced to these concepts.

Another concern for nonformal STEM programs such as 4-H, is that the volunteers delivering STEM curricula may not have a background in STEM subjects which could adversely affect the successful delivery of the curricula. In an effort to create effective STEM programs in nonformal environments, the national 4-H organization designed a collection of resources for state and local 4-H staff to provide STEM training to 4-H volunteers (Locklear, 2013). These resources were designed with the intention of preparing volunteers from a wide range of educational and professional backgrounds to effectively deliver 4-H STEM curricula. In addition to providing a blueprint for building an understanding of quality STEM programs, these resources expand the understanding of what educators should know about inquiry-based learning; further enhancing their knowledge of STEM concepts and positive youth development practices that frame 4-H STEM programming (National Research Council, 2015) thereby increasing the quality of after-school STEM programs America's youth are receiving. 4-H is one out-of-school STEM provider that has focused on improving the capacity of its staff members to facilitate productive learning experiences.

The 4-H commitment to improve the STEM skills of America's youth has been present during the organization's 110-year history. Building on its history of

hand-on science education, in 2007 4-H partnered with the Noyce Foundation to develop a nationally recognized youth development approach to STEM in out-of-school settings. A key aspect of this partnership was to create a professional development strategy to prepare state and local 4-H educators and volunteers. (National Research Council, 2015, p. 29)

The rapidly growing need to expand STEM programs in nonformal environments has exhausted existing nonformal STEM resource materials and exceeded the abilities of many volunteers and site coordinators who serve as leaders in after-school STEM programs.

### **4-H and STEM**

Although the term STEM was being used by many organizations, 4-H opted to use the term 4-H SET as programs designed to increase math skills were historically offered by 4-H, yet due to leaders concerns that 4-H SET was too restrictive the National 4-H Management Team transitioned to 4-H Science (Locklear, 2013). In 2003, the National 4-H Headquarters at the USDA, the National 4-H Council, and the Extension Committee on Organization and Policy (ECOP) 4-H Taskforce began focusing on the need to define the role of 4-H in the areas of science, engineering and technology (4-H, 2007). A vision statement and framework for reaffirming 4-H's leadership in science, engineering, and technology was developed in 2004 and in 2006 the 4-H Science Engineering and Technology (SET) Leadership Team, comprised of national, state, and county 4-H faculty and staff was created (4-H, 2007). 4-H professionals and volunteers were intended to use this framework as guide for designing, implementing, and evaluating 4-H STEM programming at local, state, and national levels (4-H, 2007). The

following four guiding principles were outlined in the framework.

1. Science, engineering and technology learning takes place in the context of the Essential Elements of 4-H youth development.
2. 4-H's approach to science, engineering and technology must include youth/adult partnerships.
3. 4-H delivers science, engineering and technology programs in a variety of contexts to diverse youth in rural, suburban and urban areas including the inner city.
4. 4-H SET programs and the curricula are based on the National Science Education Standards (NSES).

The final principle states 4-H STEM programs must be aligned with the NSES/NGSS standards and “focus on nonformal experientially-based delivery methods that address science abilities (process) and science anchors (content) in a hands-on way under the guidance of a trained (scientifically able) 4-H learning facilitator” (4-H, 2007, p. 3) in order to ensure that quality and effectiveness of 4-H STEM programming.

In regards to program development and design, the goal for 4-H STEM programs is to develop and deliver content that is contextually valid to youth in a number of settings that addresses the needs of youth from diverse backgrounds (4-H, 2007). The objective of 4-H STEM programs is that youth will increase in knowledge, skills, and competencies and experience improved attitudes in the areas of science, engineering and technology (4-H, 2007). In order to achieve the goals and objectives systems within 4-H were created to design, implement and evaluate 4-H STEM programs by developing an infrastructure of 4-H staff at every level, outline content and experiential learning standards, provide training, technical support and funding to county and state level 4-H STEM programs including resources needed for youth to explore 4-H STEM

opportunities, measure program outcomes, evaluate programs and offer support for program improvement (4-H, 2007).

Professional development is a fundamental goal of the 4-H Science framework and illustrated that professional development opportunities must be well-coordinated so that 4-H youth, adult volunteers, and staff are equipped to integrate science, engineering and technology into 4-H (4-H, 2007). The objective for 4-H STEM professional development is that youth, adult volunteers, and staff will increase in knowledge, skills and competencies (4-H, 2007). The goals and objectives for 4-H STEM professional development are achieved by developing an infrastructure that supports consistent and on-going training, involving 4-H STEM content experts in designing 4-H STEM professional development resources, delivering professional development in various formats, and creating a technology infrastructure for delivering online 4-H STEM training, resources, and support for staff and volunteers (4-H, 2007).

The goal for curriculum development has been a fundamental piece of the 4-H Science Framework. If 4-H STEM curricula is to be effective in increasing knowledge, skills, interest and competencies and improve their attitude toward science, engineering and technology an expansive selection of 4-H STEM curricula that meets NSES/NGSS and the criteria in the curricula review process established by the National 4-H Headquarters (4-H, 2007) must be available. Therefore, a system of research and evaluation designed to measure the effectiveness of 4-H STEM goals and objectives is a key component of the 4-H Science Framework (4-H, 2007). To accomplish the goals and objectives of the 4-H STEM program an infrastructure that prepares teams of youth and

adults to aid in the design and evaluation of 4-H STEM curricula must exist at the county, state, and national levels.

In the context of 4-H Youth Developmental Programming, 4-H STEM programs must rely upon its brand of nonformal experientially-based delivery method (Horton, Gogolski, & Warkentien, 2007). The 4-H nonformal experiential-based learning approach addresses science abilities and content through hands-on experiences under the guidance of a scientifically able 4-H learning facilitator (Horton et al., 2007). The 4-H STEM standards evolved through research of the national science standards that concentrated on a series of reports including *Project 2061* (Horton et al., 2007). The significance of *Project 2061* is threefold as first, it outlines the standards for teaching, learning, and curriculum development (Horton et al., 2007). Second, *Project 2061* stresses the relationship of science, engineering, and technology. NSES recognizes technology as one of its standards and engineering is recognized in *Project 2061* as a problem solving and design process. Third, extremely important, is the shifting management of abilities within the field of teaching and learning science (Horton et al., 2007). *Project 2061* influenced the shift from “separating science knowledge and science abilities to integrating all aspects of the science experience,” which complements the 4-H “learning by doing” experiential-based learning method (Horton et al., 2007).

The 1996 National Science Education Standards (NSES) were designed to guide the way K-12 science was taught across the U.S. (Horton et al., 2007). The following seven science content standards were prearranged to highlight significant points that are relevant to 4-H STEM programs.

1. Science as Inquiry-Inquiry is a step beyond “science as a process,” in which students learn skills, such as observation, inference, and experimentation. The new vision includes the process of science and requires that students combine process and scientific knowledge as they use scientific reasoning and critical thinking to develop their understanding of science.
2. Physical Science- Subject matter that focuses on science facts, concepts, principles, theories, and models in physical science.
3. Life Science- Subject matter that focuses on science facts, concepts, principles, theories, and models in life science.
4. Earth and Space Science- Subject matter that focuses on science facts, concepts, principles, theories, and models in earth and space science.
5. Science and Technology- Establishes connections between the natural and designed worlds and provides students with opportunities to develop decision-making abilities. They are not standards for engineering and technology education; rather, standards that emphasize the process of design and fundamental understandings about the enterprise of science and its link to engineering and technology. Fundamental abilities and concepts that underlie this standard include:
  - Identify a problem.
  - Identify a solution.
  - Design a solution.
  - Implement a solution.
  - Evaluate a solution
  - Communicate a problem, design, and solution.
6. Science in Personal and Social Perspectives- Help students develop decision-making skills.
7. History and Nature of Science- Reflect science as ongoing and changing. (Horton et al., 2007, p. 7)

The *Standards for Technology Literacy* (STL), developed in 2000, were designed to align the technology and design process standards with the NSES and established 20 technological standards. STL identifies content knowledge, abilities, and application to the real world and were built around a cognitive base as well as a doing/activity base. These standard include, but are not limited to “design, model making, problem solving,



controls, optimization and trade-offs, inventions, and many other human topics dealing with human innovation” (Horton et al., 2007, p. 10).

Within the National Science Standards engineering remains to be acknowledged as a problem-solving and design process within science and technology. However, no nationally recognized standards for engineering exist for K-12 education math, science, and technology. Instructors who realize the importance of engineering outcomes are taking a standards based approach in order to influence the upcoming generation of engineers (Horton, et al., 2007). The “*Standards for Technological Literacy: Content for the Study of Technology (STL)*” was developed by the International Technology Education Association (ITEEA) and its Technology for All Americans Project. The standards outlined by ITEEA are recognized by the Utah Education Network and define that in order for youth to be considered technologically literate youth must develop

- An understanding of the characteristics and scope of technology.
- An understanding of the core concepts of technology.
- An understanding of the relationships among technologies and the connections between technology and other fields of study.
- An understanding of the cultural, social, economic, and political effects of technology.
- An understanding of the effects of technology on the environment.
- An understanding of the role of society in the development and use of technology.
- An understanding of the influence of technology on history.
- An understanding of the attributes of design.
- An understanding of engineering design.

- An understanding of the role of troubleshooting, research and development, invention and innovation, and experimentation in problem solving.
- The abilities to apply the design process.
- The abilities to use and maintain technological products and systems.
- The abilities to assess the impact of products and systems.
- An understanding of and be able to select and use medical technologies.
- An understanding of and be able to select and use agricultural and related biotechnologies.
- An understanding of and be able to select and use energy and power technologies.
- An understanding of and be able to select and use information and communication technologies.
- An understanding of and be able to select and use transportation technologies.
- An understanding of and be able to select and use manufacturing technologies.
- An understanding of and be able to select and use construction technologies (International Technology Education Association, 2000).

The manner in which experientially-based STEM curriculum is designed directs focus to the way educational resources are created, particularly how the material is structured along an experiential path (Horton et al., 2007). The organization of information is commonly referred to as “curriculum components” and consists of aims, goals, and objectives; subject matter; learning experiences; and assessments. The emphasis placed on these components and the order they appear within a piece of curricula is a fundamental aspect of meaningful curriculum design. A recommendation from the *Science, Technology and Engineering (SET) Programming in the Context of 4-H Youth Development* report first suggested that 4-H “adopt the National Research

Council's (NRC) *National Science Education Standards* as the guiding set of principles for its SET curriculum planning and development process" (Horton et al., 2007, p 17). Adhering to the NRC's National Science Education Standards 4-H is afforded a greater contextual framework from which it can deliver an assortment of meaningful and relevant SET experiences for youth (Horton et al., 2007).

Today the Next Generation Science Standards (NGSS, 2013) have replaced the National Science Education Standards (National Research Council, 1996) as the standards for science education when the evolution of STEM education required updating the current standards. NGSS sets the bar for the creation of STEM that is abundant in content and practice, and organized in a logical manner thru disciplines and grades which offers all students an internationally-benchmarked science education (National Research Council, 2013, para 2). The NGSS are based on the *Framework for K-12 Science Education* and has been designed to prepare students for college and careers related to STEM. NGSS were developed through a multi-state collaboration with stakeholders who represented science, science education, higher education, and industry (National Research Council, 2013). Advisory committees composed of known nationwide as leaders in science and science education as well as business and industry provided additional reviews and guidance. Throughout the development process, the standards underwent numerous evaluations conducted by stakeholders as well as two public drafts, which allowed those who have a stake in science education an opportunity to have a say in the development of the standards. This process resulted in a set of high quality, college- and career-ready K–12 *Next Generation Science Standards* ready for state adoption (National

Research Council, 2013, para 2). As outlined by the NGSS performance expectations youth demonstrate proficiency through their ability to:

- Analyze and interpret data.
- Ask questions.
- Conduct a more thorough process of choosing the best solution.
- Construct explanations and designing solutions.
- Define problems.
- Demonstrate an understanding of several of engineering practices including design and evaluation.
- Design solutions.
- Develop possible solutions.
- Develop and use models.
- Engaging in argument from evidence.
- Improve designs.
- Obtain, evaluate, and communicate information.
- Optimize final design.
- Plan and carry out investigations.
- Use mathematics and computational thinking (NGSS, 2013).

Once states began adopting the new standards NGSS educators realized they needed tools to assist them in curriculum development (Houseal, 2015). To date, a number of tools have been developed to aid educators in this process including, *A Visual Representation of Three-Dimensional Learning*, based on *A Framework for K–12 Science Education* developed by the NRC in 2012 (Houseal, 2015). This learning model illustrates that teaching and learning science must include all three dimensions of learning (core content, big ideas/concepts, and process). When followed, curriculum is designed with all three dimensions represented: youth evolve a deeper understanding of core ideas in science and engineering fields (National Research Council, 2012). In addition to *A Visual Representation of Three-Dimensional Learning* model, NGSS network states and partners compiled resources to guide educators as they select, evaluate, and organize

learning materials, and includes the EQuIP rubric, which is used to evaluate Common Core math and ELA standards (Successful STEM Education, 2016).

Intended as a starting point for collaborative curriculum review and revision processes as well as a suggestion vehicle for curriculum developers, the EQuIP (Educators Evaluating the Quality of Instructional Products) document lists key NGSS-compliant criteria in the areas of standards alignment, instructional support, and student progress monitoring. In early results from a set of case studies of middle school science curricula—IQWST (Investigating and Questioning Our World Through Science & Technology) and THSB (Toward High School Biology)—the NGSS EQuIP rubric was found to be particularly useful in focusing reviewer attention on three features: the role of phenomena, or the occurrences that students will observe and reason about; the extent to which the three dimensions work together; and coherence as considered from the point of view of the student as well as the discipline. (Successful STEM Education, 2016)

Science and engineering practices are explicitly addressed in the NGSS, which were developed by the National Research Council (NRC), the National Science Teachers Association (NSTA), and the American Association for the Advancement of Science (AAAS), and Achieve were designed to improve K–12 sciences. NGSS does not advocate for specific curriculum or resource materials nor entail a specific scope and categorization in lesson planning but signifies a merging of and a withdrawal from previous efforts to demarcate basic K–12 science knowledge. Its emphasis on thorough year-over-year development of key science concepts and ideas, is illustrated through its three dimensional model which is composed of (1) scientific and engineering practices, (2) crosscutting concepts, and (3) disciplinary core ideas. This structured approach moves beyond simple *hands-on* and *inquiry* based learning styles and lays the foundation for a stronger focus on teaching and learning in the science classroom (Successful STEM Education, 2016).

Several learning models and rubrics have been developed by *Achieve* as a resource for educators to create and evaluate STEM curricula to ensure that youth are receiving quality programming that leads to STEM self-efficacy, STEM abilities, and STEM literacy.

In order to align with the national standards, the 4-H Science Logic Model reports that youth who participate in 4-H STEM program develop abilities and thereby may develop a future interest in post-secondary STEM degrees and STEM careers (4-H Science Logic Model, 2010). However, STEM curricula developed by Utah 4-H does not follow a development process nor is it formally evaluated using the peer review method used to evaluate nationally supported 4-H curriculum and thus may not produce the expected outcomes identified in the 4-H Science Logic Model. The numerous definitions and examples of STEM education suggest that valid STEM curricula must focus on real-world issues; present challenges that follow the engineering design process; engage youth in not only hands-on inquiry but open-ended questioning; provide youth with opportunities to learn to work as a productive team; requires the application of rigorous math and science content, and allows for numerous correct responses and reframes failure as a necessary part of learning (A. Jolly, 2014). These are sources of the constructs being measured by this study as they have been shown to increase youth STEM self-efficacy, STEM abilities, and STEM literacy. Aligning the creation and evaluation of future Utah 4-H developed STEM curricula with current NGSS may result in improved youth STEM self-efficacy, STEM abilities, and STEM literacy.

## Curriculum Development

The expanding need for valid STEM curricula specifically developed for nonformal environments such as 4-H is great as after-school programs are gaining recognition as a setting that holds great potential for increasing child and youth literacy and engagement in science. With this awareness comes a call for evidence that demonstrates after-school programs' impacts on students' knowledge, engagement, and interest in science (Hussar, Schwartz, Boiselle, & Noam, 2008).

When comprehending current events, choosing and using technology, or making informed decisions about one's healthcare, science understanding is key. Never before has our world been so complex and science knowledge so critical to making sense of it all (NGSS, 2013). However, "our nation continues to lag behind others in terms of the rigor of our science and mathematics. This situation continues to place strains on U.S. business and industry to meet growing employment need for science, technology, engineering and mathematics" (Newberry & Kueker, 2008, p. 1). Therefore, selecting and implementing rigorous and relevant curricula is paramount to success in today's educational climate (Newberry & Kueker, 2008, p.1). The term curriculum is defined as:

Lessons and academic content taught in a school or in a specific course or program. In dictionaries, *curriculum* is often defined as the courses offered by a school, but it is rarely used in such a general sense in schools. Depending on how broadly educators define or employ the term, curriculum typically refers to the knowledge and skills students are expected to learn, which includes the learning standards or learning objectives they are expected to meet; the units and lessons that teachers teach; the assignments and projects given to students; the books, materials, videos, presentations, and readings used in a course; and the tests, assessments, and other methods used to evaluate student learning. An individual teacher's curriculum, for example, would be the specific learning standards, lessons, assignments, and materials used to organize and teach a

particular course. (Hidden Curriculum, 2014, para 1)

The national focus on STEM education has captured the attention of educators, nonprofit organizations and commercial organizations. The demand for STEM curricula, has left to many organizations developing lessons plans, projects and activities to fill the curricular needs for their programs. Yet a common mistake is made among those attempting to write STEM curriculum as STEM curricula and science curricula are often confused for their hands-on, inquiry based learning approach, but valid STEM curricula focuses on real-world issues, presents a challenge that follows the engineering design process, engages youth in not only hands-on inquiry but open-ended questioning, provides youth with opportunities to learn to work as a productive team, includes rigorous math and science content, and allows for numerous correct responses and reframes failure as a necessary part of learning (A. Jolly, 2014, p 1).

Building on a 110-year history of hands-on science education, 4-H is working to improve the science, engineering, technology and applied math skills of America's youth. The partnership between the Noyce Foundation and 4-H has created a national system that is having a significant impact on improving the STEM (Science, Technology, Engineering, and Math) skills of youth in out-of-school settings. 4-H science programs have been shown to increase youth interest, engagement, skills, knowledge and aspirations in STEM education and careers. (Locklear, 2013, p. 4)

Through its experiential based learning designed STEM curricula 4-H youth gain a deeper understanding of agricultural science, electricity, mechanics, entrepreneurship, and natural sciences, as well as rocketry, robotics, bio-fuels, renewable energy, computer science, and environmental sciences to name a few. Likewise, Utah 4-H delivers STEM programming through clubs, afterschool programs, camps, and activities using STEM curricula from purchased from National 4-H and additional state produced curricula



written by Utah 4-H extension professionals. These 4-H STEM programs are “heralded as building blocks the future as they empower “youth with a vision of access to better education and better lives” (Kress, 2014, p. 6).

### **Curriculum Evaluation**

“In today’s classrooms, textbooks serve as tool and tutor, guidebook and gauge. Teachers throughout the world use texts to guide their instruction, so textbooks greatly influence how content is delivered” (Kulm, Roseman, & Treistman, 1999, p. 147)

Deciding which curriculum is appropriate requires educators to determine the extent to which the content of selected curricula emphasizes on and is associated with a clear set of substantial, age-appropriate learning goals that an organization has acknowledged as fundamental to the comprehension of and advancement in a particular subject.

Determining the validity of a curricula to support the attainment of specified learning goals careful evaluations of the curricula must be conducted (Kulm et al., 1999).

Identifying the learning goals in which the learning objectives of a curricula should be aligned is the first step in an evaluation. An analysis of curricular content begins after the learning goals have been defined as specific activities in the material are examined to determine if they address the activity’s objectives. The decision on whether the curricula addresses the stated learning objectives requires reviewers to base the evaluation on two main ideas: substance and sophistication of whether the activities include key elements of a learning goal or only match the topic presented (Kulm et al., 1999).

It is easy for a material to achieve alignment at the topic level--the table of contents of most textbooks reveals that they cover the same topic heading. However, although there are many different textbooks that cover the same topic--fractions, states of matter, graphing, weather, etc. --they can differ greatly in the specific ideas, or substance, that they cover. The distinction between activities that correspond only to the general topic of the content learning goal and activities that actually address its substance, is based on a careful study of the ideas contained in that learning goal. Reviewers also consider whether the activities are developmentally appropriate. That is, do they reflect the level of sophistication of the learning goal or are the activities targeting a learning goal at an earlier or later grade level. (Kulm et al., 1999, p. 2)

Assuring the reliability of a curricula is derived from numerous characteristics of the content-analysis procedure. First, the criteria are specific and well defined, and each is explained and clarified with indicators and examples. Second, the analysis procedure is conducted by education faculty knowledgeable in research on learning and teaching. Finally, evidence-based arguments for judgments used to reconcile ratings must appear in the final report (Kulm et al., 1999).

The development of nonformal STEM curricula by after-school programs should require a formal evaluation as many program managers, who may have no experience in curriculum development, are tasked with creating curricular resources to fill program needs. There is a legitimate concern that the organizational goals and objectives to “have a resource” could take priority and thus fail to create valid STEM curricula, effecting the quality of STEM learning youth receive. Conducting formal evaluations of STEM curricula developed within nonformal settings will ensure that youth are receiving quality STEM instruction as well as benefitting from participation in out-of-school time programs. The No Child Left Behind Act of 2001 further created pressure for educators across the educational system to critically examine the level of rigor and relevance in

curricula, specifically mathematics and science used to support local, district, state, and national learning priorities (Newberry & Kueker, 2008, p. 1).

This review of the literature concludes that in order for Utah 4-H to ensure it is promoting effective STEM programs it is necessary to examine STEM curricula published by Utah 4-H to determine if the content is valid and when implemented as designed increases STEM learning by providing fun, hands-on STEM activities that result in leading youth to a deeper understanding of STEM thereby promoting STEM self-efficacy, STEM abilities and STEM Literacy.

### **CHAPTER III**

## **METHODOLOGY**

The lack of a formal evaluation process that includes tools such as research-based rubrics and planning guides demonstrated the need to evaluate Utah 4-H STEM curricula that would result in meeting the outcomes of the 4-H STEM Logic Model. Contextual evidence based on the National 4-H Science Initiative further documents the objectives of 4-H STEM programming. The 4-H Science Checklist helped determine the validity of Utah 4-H STEM curricula and identified within the content the ability of the curricula to address youth STEM self-efficacy, STEM abilities, and STEM literacy. These three emerged based on literature definitions from the 4-H Science Logic Model outcomes. The literature reviewed in Chapter II defined STEM and STEM Education, identified successful out-of-school time STEM programs, outlined the criteria for the development and evaluation of STEM curricula, and examined the National Science Education Standards (National Research Council, 1996) and the NGSS (2013) as identified by the 4-H Science Checklist as criterion for quality 4-H STEM program.

### **Research Design**

This study sought to evaluate Utah 4-H STEM curricula used to deliver STEM programming to Utah 4-H youth. To answer the research questions and determine if the Utah 4-H STEM curricula was valid, a technique called summative content analysis, a qualitative research method, was used. “Content analysis is a careful, detailed, systematic examination and interpretation of a particular body of material in an effort to identify

patterns, themes, biases, and meanings” (Berg, 2009, p. 338). Content analysis is used across social science disciplines and can be conducted on a variety of media including written documents to examine the content using a coding operation and data interpreting process (Berg, 2009). Researchers also use content analysis to determine the validity and effectiveness of written contents (Fraenkel, Wallen, & Hyun, 2012). A summative content analysis counts words and phrases within a text and then the researcher explores the themes and meanings that appear in the data (Berg, 2009).

In this study, 13 of the 26 Utah 4-H developed STEM curricula as identified by Dave Francis (personal communication, Dave Francis, December 12, 2016) were evaluated using summative content analysis to determine if the materials were valid for addressing youth STEM self-efficacy, STEM abilities, and STEM literacy, meeting the outcomes of the 4-H Science Logic Model. As the 4-H Science Logic Model is a Theory of Change (TOC) model, TOC has been used as the conceptual framework to determine if the curricula, as an input, addresses STEM readiness goals. Randomly selected STEM curricula were examined to answer the following research questions.

1. Does Utah 4-H STEM curricula provide activities that could lead to increased youth STEM self-efficacy?
2. Does Utah 4-H STEM curricula provide content that could lead to STEM abilities?
3. Does Utah 4-H STEM curricula provide content related to STEM literacy?

### **Population and Sample**

The population was comprised of 26 Utah 4-H developed STEM curricula as identified by Dave Francis, Director of 4-H Science and Natural Resources (personal

communication, Dave Francis, December 12, 2016). A sample size power calculator determined the sample size to be three from a total of 26 but as this research is qualitative in nature a more conservative approach was taken to add additional confidence in the findings by randomly selecting 50% of the population, or 13 curricula. To ensure the random selection of the curricula being evaluated the titles of all 26 curricula were placed into an Excel spreadsheet and sorted alphabetically A-Z, therefore A = 1, -Z = 26. A random number generator powered by Random.org that uses atmospheric noise rather than the pseudo-random number algorithms typically used in computer programs was used to select the curricula that would be evaluated. Within the Random.org the parameters were set 1-26 to match the number of Utah 4-H STEM. Once the parameters were set, the researcher ran the random number generator until the first 13 non-reoccurring numbers representing the curricula selected for evaluation appeared. The curricula selected as a result of the random number generator were as follows 1 = Sustainable You, 2 = Art of Math, 3 = Kitchen Science, 4 = Code Clubs, 5 = Magician's Laboratory, 6 = Forces of Nature, 7 = Geology, 8 = An Unfortunate Camp, 9 = Robotics, 10 = Space Explorers, 11 = Bugs: A Creepy Crawly Adventure, 12 = FUN-damental Science, and 13 = Multi-Family Clubs.

### **Researcher Subjectivity**

Researchers who work with qualitative methods elaborate on practices, personal experiences, and educational background that would possibly influence the study. The researcher, has experience using Utah 4-H STEM curricula in 4-H settings, so this may

create an “expert blind spot.” In an effort to mitigate bias two, professors have helped with the identification of the constructs and code terminology to ensure in the data analysis. Throughout the coding process, the researcher monitored her experiences and considered any possible bias while coding and hope this awareness along with the professor support resulted in more accurate results.

### **Data Collection**

Only the instructional content was analyzed. Frequency counts of words and phrases that reflect the constructs (STEM self-efficacy, STEM abilities, STEM literacy) from the 13 curricula were coded for using NVivo. A Computer Aided Qualitative Data Analysis Software, NVivo facilitates in-depth qualitative analysis of textual and audiovisual data sources, including collecting and importing data, organizing and allows users to classify and code data, as wells as add interpretations and notes. Once text has been coded NVivo software includes data query and search features that create models, maps, and graphs so that analysis findings can be displayed textually and visually (QSR International, 2017). These functions extract characteristics from a textual body and identifies themes (Trammell, 2014).

Common phrase counts from the 13 selected Utah 4-H STEM curricula were examined using the coding sheet to complete the content analysis. This qualitative research helped to determine if the STEM constructs existed in the curriculum. Text with high frequency counts were compared to the concepts identified in each construct as defined by the literature.

*Research question one: Determine if Utah 4-H STEM curricula provided activities that could lead to increased youth self-efficacy.*

To answer research question one, hands-on activities identified in the curricula were coded using terms and phrases acknowledged by Bandura (1994) and the Science, Engineering, and Technology (SET) Programming in the Context of 4-H Youth Development report (Horton et al., 2007) as sources for STEM self-efficacy.

*Research question two: Determine if Utah 4-H STEM curricula provided content that could lead to STEM abilities.*

To answer research question two, STEM abilities were coded using terms and phrases identified in the Science, Engineering, and Technology (SET) Programming in the Context of 4-H Youth Development (Horton, et al., 2007), the 4-H Science Checklist (4-H Science Program Design, 2013), National Science Education Standards (National Research Council, 1996), the Next Generation Science Standards (2013), and the 4-H Science Initiative Framework (Locklear, 2013).

*Research question three: Determine if Utah 4-H STEM curricula provide content related to STEM literacy.*

To answer research question three, STEM literacy was coded using terms and verbs associated with the revised Bloom's Taxonomy of Learning within the categories remembering, understanding, applying, analyzing, evaluating, and creating (L. W. Anderson & Krathwohl, 2001). Remembering was described as asking participants to recall or recognize information, ideas or principles that they learned from an activity. The researcher searched for terms like list, define, describe, name, recall, label, identify,



match, memorize, or recognize. Understanding is described as participants comprehending information based on their prior learning from activities but cannot apply to other activities. The researcher coded for “understanding” by searching for terms like explain, summarize, describe, explain, give examples, review, or summarize. The code “applying” was described as participants selecting, and using information or principles from an activity to complete a task. Terms used to identify the “applying” code were compute, solve, demonstrate, construct, produce, show, use, or solve. The code “analyzing” was described as participants distinguishing, classifying, and relating the information, assumptions, and evidence of a question or statement. The researcher coded for “analyzing” by searching for terms like analyze, differentiate, relate, or distinguish. Synthesizing was described as participants originating, integrating, and combining ideas into a product or task that is new to them. The researcher coded for “synthesizing” by searching for terms such as create, design, create, invent, develop, assemble, construct, create, or prepare. The code “evaluating” was described as assessing or critiquing on the basis of criteria or what was learned from an activity. The “evaluating” code was identified by searching for terms such as judge, recommend, critique, assess, choose, conclude, defend, describe, estimate, evaluate, or explain.

### **Data Analysis**

The three primary constructs, STEM self-efficacy, STEM abilities, and STEM literacy were used as coding terms. STEM self-efficacy was coded according terms and phrases as defined by Bandura (1994) and in the SET Programming in the Context of 4-H

Youth Development report (Horton et al., 2007). As “doing” activities promote self-efficacy (Bandura, 1994), words and phrases within the curriculum with these types of terms or actions were coded as addressing the self-efficacy construct. Words and phrases in the curricula that included the content addressing SET Programming in the Context of 4-H Youth Development (Horton et al., 2007), the 4-H Science Checklist (4-H Science Program Design, 2013), National Science Education Standards (National Research Council, 1996), the NGSS (2013), and the 4-H Science Initiative Framework (Locklear, 2013) terms were coded as STEM abilities. Words and phrases that included terminology and verbs associated with Bloom’s Updated Taxonomy of Learning (Krathwohl, 2002) for remembering, understanding, applying, analyzing, evaluating and creating were coded for STEM literacy (the ability to demonstrate an understanding of STEM).

Identifying the frequency of terms and phrases related to STEM self-efficacy, STEM abilities, and STEM literacy within Utah 4-H STEM curricula was to determine a valid way to review the resources used to promote STEM programs and aid in the development of future STEM resources. After curricula was coded for each construct the data for each research question was compiled using the NVivo data analysis software. Frequency counts illustrated within the instructional content the appearance of terms associated with the constructs. For STEM self-efficacy content was coded using terms and phrases that reflected hands-on activities, open ended questions, and engaged youth in learning through building, creating, exploring, making, discovering, testing, planning, experiencing, measuring, draw, etc. (see Appendix C for complete list). For STEM abilities content was coded using terms and phrases that reflected opportunities in which

youth were required to analyze, build, categorize, classify, collaborate, collect data, communicate, compare, demonstrate, etc. as part of the activity (see Appendix D for complete list). STEM literacy frequency counts illustrated within the instructional content identified the appearance of verbs associated with Bloom's Taxonomy of Learning that reflected opportunities for youth the demonstrate understanding, apply skills, analyze outcomes, evaluate the process and create solutions which promote STEM literacy (see Appendix E for complete list).

## CHAPTER IV

### RESULTS

Focusing on concepts from the TOC model and outcomes from the 4-H Science Logic Model, the purpose of this study was to determine if Utah 4-H STEM curricula were valid for addressing youth STEM self-efficacy, STEM abilities, and STEM literacy, meeting the outcomes of the 4-H Science Logic Model. To answer the research questions, a summative content analysis to collect qualitative data was conducted. A random sampling method was applied to select 13 of the 26 Utah 4-H STEM curricula used as the sample population. The curricula, accessible through digital download in PDF format was uploaded and coded in NVivo version 11.0.

Overall the curricula examined in the study presented activities 37 hands-on activities that had no connection to a STEM concept (i.e., make a wand, make a cauldron, make a snack) although hands-on, were not coded as sources of STEM self-efficacy. Fifty-two activities presented youth with opportunities acquire abilities through to building, drawing, demonstrating, etc., but did not make a connection to STEM concepts (i.e., Jitter Critter, Slithering Snake, Project Reptile) and identified more closely with arts and crafts activities were not coded as sources of STEM abilities. Activities that that presented instructions in sequential order resulting in identical projects and those that had no connection to a STEM concept were not coded as sources of STEM literacy as youth did not work independently to demonstrate knowledge of STEM concepts presented. In addition, activities that allowed youth to work independently but made no connection to STEM concepts were not coded as sources of STEM literacy. The study also revealed

that in regards to STEM education, Utah 4-H STEM curricula focused primarily on science experiments while technology, engineering, and mathematics did not make up a significant portion of the activities as noted by the terminology in the instructional content.

### **Curricular Unit Results to Research Questions One, Two, and Three**

Results to the research questions are presented in this chapter. The following research questions were used to guide this qualitative study:

1. Does Utah 4-H STEM curricula provide activities that could lead to increased youth STEM self-efficacy?
2. Does Utah 4-H STEM curricula provide content that could lead to STEM abilities?
3. Does Utah 4-H STEM curricula provide content related to STEM literacy?

### **4-H Multi-Family Club**

According to the preface, the goal of the *4-H Multi-Family Club* curriculum is to bring families in a community together through participation in fun learning activities that include science experiments, cooking, community service, and gardening where members will experiment with new things and learn more about the world around them (Utah 4-H, 2011b). The *4-H Multi-Family Club* did not specify grade levels appropriate for this curriculum.

Research question 1, results for- STEM self-efficacy: The sources of STEM self-efficacy in the activities were identified as open-ended questions and opportunities for youth to mix, measure, observe, discuss, experiment, work together, and build. Of the 11

activities presented, there were seven references associated with STEM self-efficacy in the instructional content (Table 1).

Research question 2, results for- STEM abilities: The sources of STEM abilities in the activities were identified as opportunities for youth to make predictions, use tools, observe, carry out experiments, test, communicate, and reason through hands-on activities. Of the 11 activities presented, six references were associated to STEM abilities in the instructional content (Table 1).

Research question 3, results for- STEM literacy: The sources of STEM literacy in the activities were identified in hands-on opportunities for youth to measure, experiment, analyze, change, take part in, discuss, make predictions, apply, and test. Of the 11 activities presented, 4.24% of the references were associated to STEM literacy in the instructional content (Table 1).

### **An Unfortunate Camp**

Based on the first three books from the book series “*A Series of Unfortunate Events*” the goal, according to the preface, of the *An Unfortunate Camp* curriculum is to have youth recognize the work of scientists and to see the characteristics of performing experiments through fun, hands-on activities that teach basic science principles. By exploring the science behind inventions, studying reptiles and various creative projects youth will learn through exploration and experimentation. *An Unfortunate Camp* was designed for grades 3-5, however it is suggested in the preface that the curriculum could be adapted to fit most age ranges (Utah 4-H, 2011a).

Table 1

*References to STEM Self-Efficacy, STEM Abilities, and STEM Literacy in Curricular Content*

Curricula	STEM self-efficacy	STEM abilities	STEM literacy: Bloom's taxonomy of learning					
			Remembering	Understanding	Applying	Analyzing	Evaluating	Creating
4-H Multi-Family Club	7	6	8	0	8	2	1	7
An Unfortunate Camp	21	39	29	6	22	13	6	53
Art of Math	13	12	17	2	5	3	4	9
Bugs, A Creepy Crawly Adventure	16	15	30	1	3	2	3	8
Code Club	9	3	6	2	7	3	6	8
Forces of Nature	13	17	7	3	2	4	5	9
FUN-damental Science	27	57	39	6	13	11	11	43
Geology	6	6	6	3	1	3	3	2
Kitchen Science	11	15	5	1	11	1	1	7
Magician's Laboratory	21	34	24	2	7	0	2	26
Robotics	6	5	12	1	3	2	8	4
Space Explorers	20	24	31	2	7	3	6	25
Sustainable You	15	20	37	8	7	13	21	12

Research question 1, results for STEM self-efficacy: The sources of STEM self-efficacy in were identified as open-ended questions and opportunities for youth work in groups and engage in hands-on activities that required youth to discuss, observe, make predictions, build, test, identify a problem, create, measure, hypothesize, and experiment. Of the 25 activities presented, 21 references were associated to STEM self-efficacy in the instructional content (Table 1).

Research question 2, results for STEM abilities: The sources of STEM abilities in the activities were identified in hands-on activities that required youth to collect data, analyze, observe, question, compare, categorize, communicate, build, test, design, use tools, make predictions, and measure. Of the 25 activities presented, 39 references were associated to STEM abilities in the instructional content (Table1).

Research question 3, results for- STEM literacy: The sources of STEM literacy in the activities were identified in hands-on activities that required youth to take part in, discuss, categorize, analyze, compare, conclude, decide, experiment, apply, build, test, make predictions, identify problems, and create solutions. Of the 25 activities presented, 9.3% of the references were associated to STEM literacy in the instructional content (Table 1).

### **Discover 4-H Art of Math**

The *Discover 4-H Art of Math* is meant to be an introductory curriculum to 4-H that builds math skills among youth. *Discover 4-H Art of Math* was designed for grades 3-12.



Research question 1, results for STEM self-efficacy: The sources of STEM self-efficacy were identified as open-ended questions and in hands-on activities that required youth to draw, design, create, experiment, test, observe, discuss, test, build, and measure. Of the 13 activities presented, 13 references were associated to STEM self-efficacy in the instructional content (Table 1).

Research question 2, results for STEM abilities: The sources of STEM abilities in the activities were identified in hands-on activities that required youth to solve a problem, communicate, draw, design, build, analyze, use tools, observe, compare, and test. Of the 13 activities presented, 12 references were associated to STEM abilities in the instructional content. (Table1).

Research question 3, results for STEM literacy: The sources of STEM literacy in the activities were identified in hands-on activities that required youth to solve a problem, discuss, take part in, create, decide, design, apply, analyze, build, experiment, test, and measure. Of the 13 activities presented, 15.18% of the references were associated to STEM literacy in the instructional content (Table 1).

### **Bugs! A Creepy, Crawly Adventure**

The *Bugs! A Creepy Crawly Adventure Camp* preface states that the goal of the curriculum is for youth to gain an understanding and relate to the work of scientists by experiencing the aspects of conducting experiments that teach basic science principles (Utah 4-H, n.d). Campers will learn through exploration and experimentation. According to the preface the *Bugs! A Creepy Crawly Adventure* curriculum was designed for grades

1-2, but suggests that it could be adapted to fit other age ranges.

Research question 1, results for- STEM self-efficacy: The sources of STEM self-efficacy were identified as open-ended questions and in hands-on activities that required youth to create, draw, build, observe, and discuss. Of the 31 activities presented, 17 references were associated to STEM self-efficacy in the instructional content (Table 1).

Research question 2, results for STEM abilities: The sources of STEM abilities in the activities were identified in activities that required youth to build, communicate, observe, analyze, collect data, draw, use tools, measure, test, experiment, and make predictions. Of the 31 activities presented, 15 references were associated to STEM abilities in the instructional content (Table1).

Research question 3, results for STEM literacy: The sources of STEM literacy were identified in hands-on activities that required youth to discuss, create, take part in, analyze, experiment, observe, build, measure, compare, apply, and make predictions. Of the 31 activities presented, 2.92% of the references were associated to STEM literacy in the instructional content (Table 1).

### **Discover 4-H Code Clubs**

The *Discover 4-H Code Club* curriculum was designed to introduce youth to computer programming. By introducing the basic concepts of computer science with “drag-and-drop” programming language and JavaScript. Activities included the use of functions, function calls, and parameters in computer coding, troubleshooting and debugging, review basic algorithms and programming, work as teams and to find and

correct bugs in existing code, incorporate various coding functions to create works of art, and work as teams to create original unplugged games. *Discover 4-H Code Clubs* was designed for grades 3-12.

Research question 1, results for STEM self-efficacy: The sources of STEM self-efficacy were identified as open-ended questions and in hands-on activities that required youth to draw, design, create, experiment, test, observe, discuss, build, and measure. Of the 11 activities presented, 11 references were associated to STEM self-efficacy in the instructional content (Table 1).

Research question 2, results for STEM abilities: The sources of STEM abilities in the activities were identified as activities that required youth to use tools, draw, design, experiment, test, observe, communicate, build, and measure. Of the 11 activities presented, three references were associated to STEM abilities in the instructional content (Table 1).

Research question 3, results for- STEM literacy: The sources of STEM literacy were identified in hands-on activities that required youth to discuss, apply, and take part in. Of the 11 activities presented, 8.3% of the references were associated to STEM literacy in the instructional content (Table 1).

### **Discover 4-H Forces of Nature**

The objective of the *Discover 4-H Forces of Nature* curriculum is to provide youth with hands-on activities that address basic science principles and explore the science of earthquakes, floods, fires, and extreme weather conditions which are all forces

of nature found on Earth. *Discover 4-H Forces of Nature* was designed for grades 3-12.

Research question 1, results for STEM self-efficacy: The sources of STEM self-efficacy were identified as open-ended questions, group activities, and in hands-on activities that required youth to plan, draw, design, measure, test, redesign, predict, observe, and discuss. Of the 11 activities presented, 12 references were associated to STEM self-efficacy in the instructional content (Table 1).

Research question 2, results for STEM abilities: The sources of STEM abilities were identified as group activities, and in hands-on activities that required youth to plan, draw, design, measure, test, redesign, predict, observe, and communicate. Of the 11 activities presented, 17 references were associated to STEM abilities in the instructional content (Table 1).

Research question 3, results for STEM literacy: The sources of STEM literacy were identified in hands-on activities that required youth to make predictions, take part in, experiment, build, design, test, discuss, apply, and measure. Of the 11 activities presented, 6.31% of the references were associated to STEM literacy in the instructional content (Table 1).

### **Fun-Damental Science Camp**

According to the preface the goal of the *Fun-Damental Science Camp*, curriculum is for youth to gain an understanding and relate to the work of scientists by experiencing the aspects of conducting experiments that teach basic science principles (Utah 4-H, 2009). To achieve the goal youth will engage in hands-on and meaningful activities that

teach basic science principles through 40 activities that explore bubbles, potions, light as campers are introduced to chemical reactions, learn about famous scientists, and discover the “fun” in science activities through exploration and experimentation. “*Fun-damental Science*” was designed for grades 1-2, but the preface suggests that it could be adapted to fit most elementary age ranges

Research question 1, results for STEM self-efficacy: The sources of STEM self-efficacy were identified as open-ended questions, group activities, and in hands-on activities that required youth to measure, observe, discuss, predict, experiment, test, draw, design, and build. Of the 42 activities presented, 34 references were associated to STEM self-efficacy in the instructional content (Table 1).

Research question 2, results for STEM abilities: The sources of STEM abilities were identified as group activities, and in hands-on activities that required youth to measure, observe, use tools, communicate, predict, experiment, test, draw, design, and build. Of the 42 activities presented, 57 references were associated to STEM abilities in the instructional content (Table1).

Research question 3 results for STEM literacy: The sources of STEM literacy were identified in hands-on activities that required youth to analyze, take part in, discuss, make predictions, experiment, test, compare, apply, measure, build, and design. Of the 42 activities presented, 4.23% of the references were associated to STEM literacy in the instructional content (Table 1).

### **Discover 4-H Geology**

The *Discover 4-H Geology* was designed as an introductory curriculum. Within the six activities geology is explored through fun, hands-on activities that teach basic science principles. *Discover 4-H Geology* was designed for grades 3-12.

Research question 1, results for STEM self-efficacy: The sources of STEM self-efficacy were identified as open-ended questions and in hands-on activities that required youth to observe, test, measure and hypothesize. Of the six activities presented, six references were associated to STEM self-efficacy in the instructional content (Table 1).

Research question 2, results for STEM abilities: The sources of STEM abilities were identified in hands-on activities that required youth to observe, test, use tools, measure and make predictions. Of the six activities presented, six references were associated to STEM abilities in the instructional content (Table1).

Research question 3, results for STEM literacy: The sources of STEM literacy were identified in hands-on activities that required youth to explain, create, compare, discuss, apply, take part in, experiment, measure, test, and analyze. Of the six activities presented, 8.94% of the references were associated to STEM literacy in the instructional content (Table 1).

### **Discover 4-H Kitchen Science**

The *Discover 4-H Kitchen Science* curricula was designed for youth grades 3-12 to explore basic chemistry, physics, and biology using common items from the kitchen.

Research question 1, results for STEM self-efficacy: The sources of STEM self-

efficacy were identified as open-ended questions and in hands-on activities that required youth to make predictions, measure, observe, experiment, and test. Of the 11 activities presented, 11 references were associated to STEM self-efficacy in the instructional content (Table 1).

Research question 2, results for- STEM abilities: The sources of STEM abilities were identified in hands-on activities that required youth to make predictions, measure, observe, and use tools, experiment, and test. Of the 11 activities presented, 15 references were associated to STEM abilities in the instructional content (Table 1).

Research question 3, results for- STEM literacy: The sources of STEM literacy were identified in hands-on activities that required youth to make predictions, take part in, experiment, measure, analyze, discuss, apply, change, compare, and test. Of the 11 activities presented, 8.36% of the references were associated to STEM literacy in the instructional content (Table 1).

### **Magician's Laboratory**

According to the preface the goal of the *Magician's Laboratory* is for youth to understand the work of scientists and to see the aspects of performing experiments relating to the work of scientists through meaningful hands-on activities. This curriculum is intended for youth grades 2-3. Through activities that include writing with invisible ink and learning the secret behind the famous table cloth trick the objective states that youth will understand gravity, reactions, optical illusions, and learn about the science behind magic.

Research question 1, results for STEM self-efficacy: The sources of STEM self-efficacy were identified as open-ended questions and in hands-on activities that required youth to make predictions, measure, observe, experiment, and test. Of the 37 activities presented, 21 references were associated to STEM self-efficacy in the instructional content (Table 1).

Research question 2, results for STEM abilities: The sources of STEM abilities were identified in hands-on activities that required youth to make predictions, measure, observe, use tools, experiment, and test. Of the 37 activities presented, 34 references were associated to STEM abilities in the instructional content (Table1).

Research question 3, results for STEM literacy: The sources of STEM literacy were identified in hands-on activities that required youth to discuss, build, measure, take part in, test, experiment, make predictions, apply, and analyze. Of the 37 activities presented, 2.08% of the references were associated to STEM literacy in the instructional content (Table 1).

### **Discover 4-H Robotics**

The *Discover 4-H Robotics* curriculum was designed as an introductory club resource. Youth participants will construct a simple robot that can perform tasks on command by writing programs on a computer.

Research question 1, results for STEM self-efficacy: The sources of STEM self-efficacy were identified as open-ended questions and in hands-on activities that made connections to real-world issues requiring youth to identify a problem, research a



problem, develop a solution, select a solution, build a prototype, evaluate, share their findings, measure, observe, and test. Of the six activities presented, six references were associated to STEM self-efficacy in the instructional content (Table 1).

Research question 2, results for STEM abilities: The sources of STEM abilities were identified in hands-on activities that made connections to real-world issues requiring youth to identify a problem, research a problem, develop a solution, select a solution, use tools, build a prototype, evaluate, share their findings, measure, observe, and test. Of the six activities presented, five references were associated to STEM abilities in the instructional content (Table1).

Research question 3, results for STEM literacy: The sources of STEM literacy were identified in hands-on activities that made connections to real-world issues requiring youth to take part in, explain, discuss, apply, measure, identify a problem, research a problem, develop a solution, select a solution, build a prototype, evaluate, share their findings, analyze, and test.

Of the six activities presented, 7.16% of the references were associated to STEM literacy in the instructional content (Table 1).

### **Space Explorers**

According to the preface the goal of the *Space Explorers* camp curriculum is for youth to gain an understanding and relate to the work of scientists through examining the Solar System to learn about the planets, comets, stars, rockets and about the night sky through hands-on activities. “*Space Explorers*” was designed for grades 1-3.

Research question 1, results for STEM self-efficacy: The sources of STEM self-efficacy were identified as open-ended questions and in hands-on activities that required youth to build, test, discuss, draw, make predictions, experiment, measure, and estimate. Of the 32 activities presented, 20 references were associated to STEM self-efficacy in the instructional content (Table 1).

Research question 2, results for STEM abilities: The sources of STEM abilities were identified in hands-on activities that required youth to build, test, communicate, draw, make predictions, experiment, measure, and use tools. Of the 32 activities presented, 24 references were associated to STEM abilities in the instructional content (Table 1).

Research question 3, results for STEM literacy: The sources of STEM literacy were identified in hands-on activities that required youth to discuss, take part in, build, experiment, test, apply, measure, make predictions, design, and compare. Of the 32 activities presented, 3% of the references were associated to STEM literacy in the instructional content (Table 1).

### **Sustainable You**

According to the preface the goal of the *Sustainable You* camp curriculum is for youth was designed to help youth understand what it means to be sustainable through fun, interactive activities based around the five major areas of sustainability: land, air, food, energy, and water. This camp is written for grades 4-6 but it is suggested in the preface that it could be adapted for all ages.

Research question 1, results for STEM self-efficacy: The sources of STEM self-efficacy were identified as open-ended questions and in hands-on activities that required youth identify problems and solutions to real-world issues, discuss, measure, build, reflect, experiment, and observe. Of the 37 activities presented, 15 references were associated to STEM self-efficacy in the instructional content (Table 1).

Research question 2, results for STEM abilities: The sources of STEM abilities were identified in hands-on activities that required youth identify problems and solutions to real-world issues, communicate, measure, build, use tools, experiment, and observe. Of the 37 activities presented, 20 references were associated to STEM abilities in the instructional content (Table 1).

Research question 3, results for STEM literacy: The sources of STEM literacy were identified in hands-on activities that required youth to identify problems and solutions, discuss, apply, take part in, explain, categorize, classify, measure, build, analyze, summarize, and conclude. Of the 37 activities presented, 4.44% of the references were associated to STEM literacy in the instructional content (Table 1).

## **Overall Results**

*Research Question 1: Does Utah 4-H STEM curricula provide activities that could lead to increased youth STEM self-efficacy?*

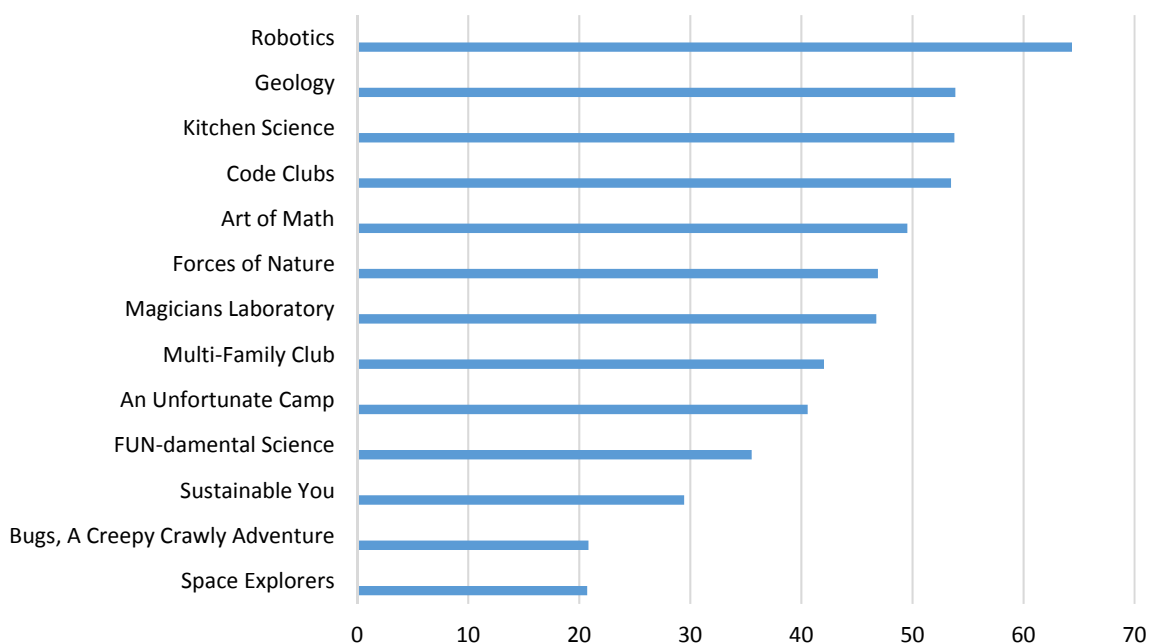
This research question examined the ability of the content within the curricula to promote STEM self-efficacy among youth participants. The results were gathered by identifying hands-on activities in the curricula and then coded using terms and phrases

acknowledged by Bandura (1994) and the SET Programming in the Context of 4-H Youth Development report (Horton et al., 2007) as sources for STEM self-efficacy.

While Utah 4-H STEM curricula provided activities that addressed self-efficacy, of the 242 activities presented across all 13 curricula, only 179 of the activities addressed STEM self-efficacy. The sources of STEM self-efficacy were identified as open-ended questions and in hands-on activities that required youth to create, draw, build, observe, and discuss STEM related subjects on a beginner level but provided no suggestions for adapting activities to account for the ages and stages of youth receiving the instruction. The Utah 4-H STEM curricula that best provided activities that could lead to STEM self-efficacy were *Discover Robotics*, *Discover Geology*, *Discover Kitchen Science*, *Discover Code Clubs*, and *Discover the Art or Math* (Figure 1).

*Research question two: Determine if Utah 4-H STEM curricula provided content that could lead to STEM abilities.*

To answer research question two, STEM abilities were coded using terms and phrases identified in the SET Programming in the Context of 4-H Youth Development (Horton et al., 2007), the 4-H Science Checklist (4-H Science Program Design, 2013), National Science Education Standards (National Research Council, 1996), the NGSS (2013), and the 4-H Science Initiative Framework (Locklear, 2013). While Utah 4-H STEM curricula provided activities that developed skills among youth, of the 242 activities presented across all 13 curricula 253 references to STEM abilities were identified within the content with 52 references being identified as skill building activities with no connection to STEM. Content that could lead to STEM abilities is linked to



*Figure 1.* Curricular ability to provide content that could lead to STEM self-efficacy.

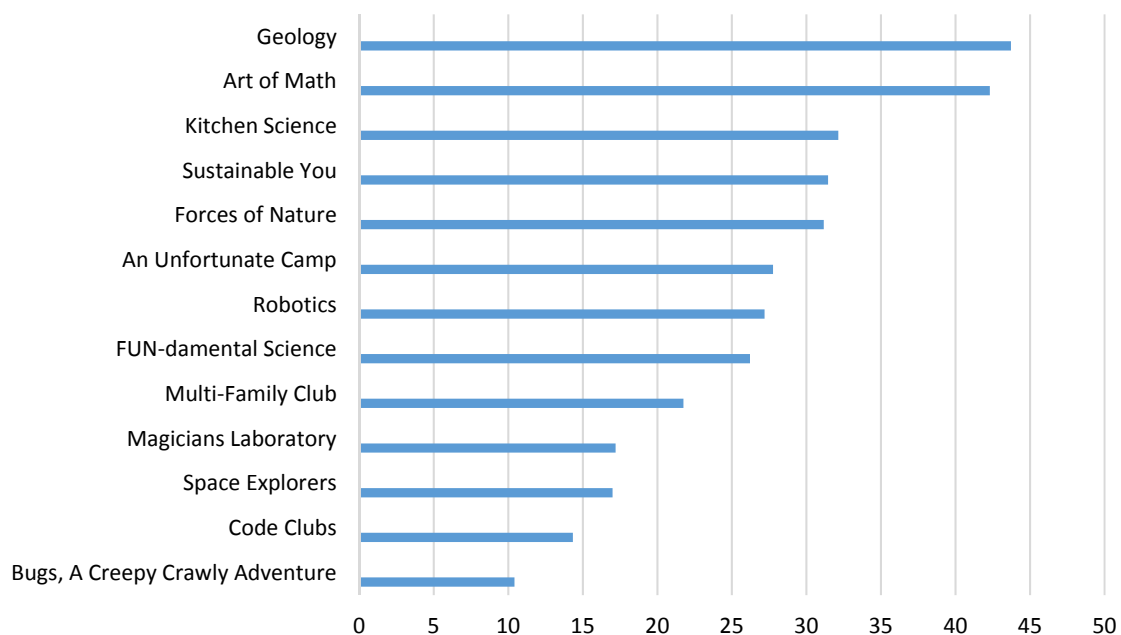
curricula that provides content which addresses STEM self-efficacy with hands-on activities where youth make predictions, measure, observe, use tools, experiment, and test STEM related subjects. The five Utah 4-H STEM curricula that best addressed activities that could lead to STEM abilities were *Discover Geology*, *Discover the Art of Math*, *Discover Kitchen Science*, *Sustainable You*, and *Discover Forces of Nature* (Figure 2).

*Research question three: Determine if Utah 4-H STEM curricula provide content related to STEM literacy.*

To answer research question three, STEM literacy was coded using terms associated with the verbs recognized in the revised Bloom's Taxonomy of Learning within the categories of remembering, understanding, applying, analyzing, evaluating,

and creating (L. W. Anderson & Krathwohl, 2001).

STEM literacy is developed through opportunities for youth to apply their abilities to remember, and demonstrate an understanding of the concepts learned to apply, analyze, evaluate, and create projects tied to real-world issues independently. While Utah 4-H STEM curricula provided activities that promoted STEM literacy among youth, of the 242 activities presented across all 13 curricula 251 references to remembering, 37 references to understanding, 96 references to applying, 60 references to analyzing, 77 references to evaluating, and 201 references to creating were identified within the content as STEM literacy building activities. Utah 4-H STEM curricula provided activities provided few opportunities for youth build STEM literacy as most activities were identical and follow a chronological instructional for completing projects. Furthermore, as noted by the terminology used in the instructional content, few opportunities to apply



*Figure 2.* Curricular ability to provide content that could lead to STEM abilities.

learning independently were identified as activities were presented sequentially producing identical results for each youth. The five Utah 4-H STEM curricula that best addressed activities that could lead to STEM literacy were *Discover the Art of Math*, *An Unfortunate Camp*, *Discover Geology*, *Discover Kitchen Science*, and *Discover Code Clubs* (Figure 3).

The National 4-H Science Logic Model (see Appendix A) indicates the outcomes of 4-H STEM programming to be STEM self-efficacy, STEM abilities, and STEM literacy. Across all 13 curricula the activities present very basic STEM concepts on a beginner level and provide no suggestions for adapting activities to account for the ages and stages of youth receiving the instruction. This study found a disconnect, as defined by the frequency counts, between STEM self-efficacy and the activities STEM concepts.

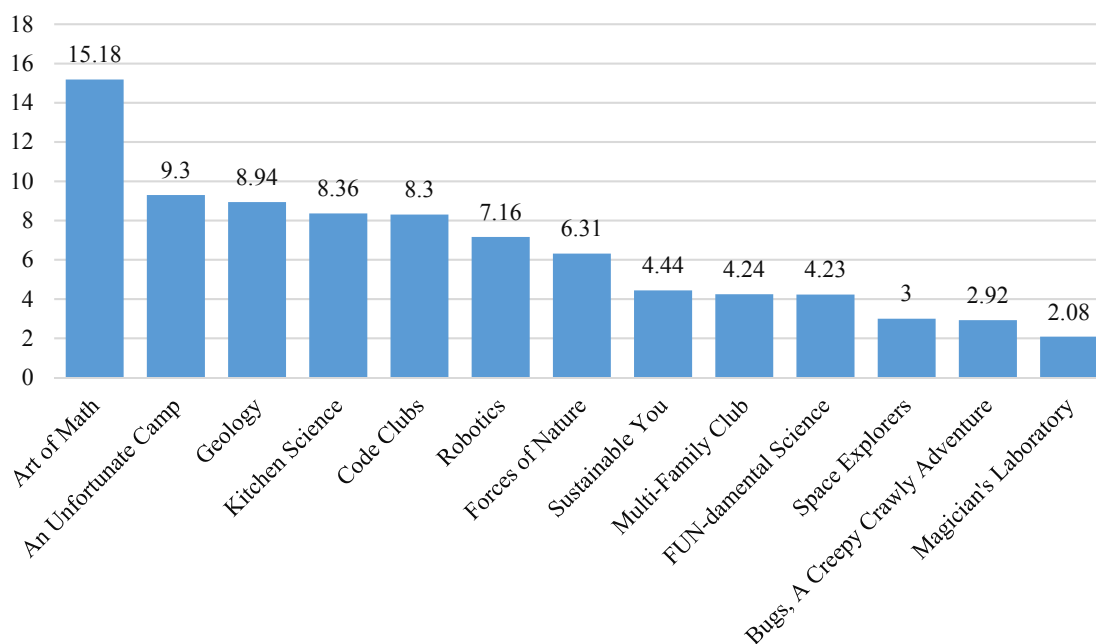


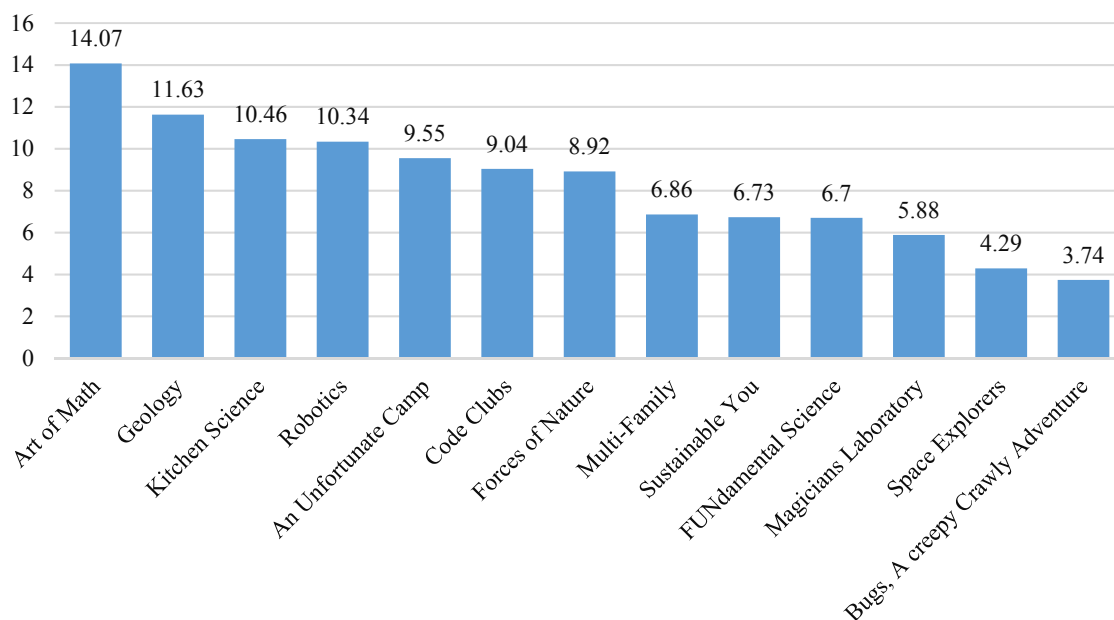
Figure 3. Curricular ability to provide content that could lead to STEM literacy: Overall.

In other words, the activities which promoted self-efficacy did not include opportunities for students to explain the science concepts, thereby making meaning of the science concepts. In many instances there were hands-on or active learning activities that were identified as arts and crafts projects but these projects did not provide an explicit link to the science concepts. For example: In the Taffy Pull activity (Multi-family, Learning Activity 2) participants were required to measure, observe, and answer open-ended questions pertaining to the temperature and what might happen if the taffy was removed before or after it reached the optimum heat, yet the instructional content failed to provide the scientific background of how taffy is formed, the chemical reaction that takes place, or the importance of heating taffy to 250 degrees. Therefore, the activity may lead to increased self-efficacy and build abilities but fails to provide the necessary content that would promote STEM self-efficacy, STEM abilities, and STEM literacy.

A ranking of the curricula that best met the three constructs was compiled by adding the total frequency counts for STEM self-efficacy, STEM abilities, and STEM literacy for each curriculum and dividing by the total number of curricula evaluated (13). The results showed that the resources that best addressed the outcomes of the 4-H Science Logic Model were the *Discover the Art of Math*, *Discover Geology*, *Discover Kitchen Science*, *Discover Robotics*, *An Unfortunate Camp*, *Discover Code Clubs*, and *Discover Forces of Nature* (Figure 4).

The results of this study are presented by curricular unit along with the results to each of the research questions. Tables displaying the number of construct references within each curricular resource and word clouds were used to provide a visual





*Figure 4.* Curricular ability to address the outcomes of the 4-H science logic model.

representation of the statistical results. A word cloud is a unique visual graphic of text in which the more frequently used words are emphasized by appearing more prominent in the visualization (McNaught & Lam, 2010). Word clouds can recognize trends and patterns that would may be difficult to see in a curricular format.

Repeatedly appearing keywords are more noticeable in a word cloud. Words that might go unnoticed within the text are emphasized in larger text making them pop out when displayed in a word cloud (McKee, 2014). NVivo was used to produce word-cloud analyses of the terms and phrases associated with the three research constructs to identify the words most frequently appearing in the selected curricula (see Figures 5-7).





## **CHAPTER V**

### **CONCLUSIONS AND RECOMMENDATIONS**

Utah 4-H can improve the quality of its STEM programs by applying the findings of this study to set forth criteria that requires learning activities to include two or more of the STEM subjects, create a research based rubric for the evaluation of state produced STEM curricula, developing a uniform template for the creation of STEM curricula, and implementing meaningful trainings for professionals and volunteers overseeing STEM programs. Overall, Utah 4-H STEM curricula did not present activities that addressed STEM self-efficacy, STEM abilities, and STEM literacy in a cohesive manner thereby failing to meet the outcomes of the National 4-H STEM Logic Model. These constructs are learned sequentially, as youth must have a firm sense of STEM self-efficacy, gained through hands-on STEM activities (create, build, etc.) in order to acquire STEM abilities (make predictions, measure, etc.). Once youth have gained a sense of STEM self-efficacy and acquired skills associated with STEM abilities, youth experience STEM literacy which is demonstrated through their capacity to remember, understand, apply, analyze, evaluate and create projects that address real-world issues independently. By illustrating which activities cohesively addressed STEM self-efficacy, STEM abilities, and STEM literacy, Utah 4-H can use these findings to improve the quality of existing and future STEM curricula.

#### **Conclusions and Implications**

*Objective 1: Determining if Utah 4-H STEM curricula addressed the 4-H Science*

*Logic Model*

Based on the findings of the study, Utah 4-H should revise its existing STEM curricula. The resources examined contained activities in which opportunities to build self-efficacy, abilities, and literacy were present the connection was weak. However, hands-on activities associated with building self-efficacy and abilities were presented across all 13 curricula, hands-on activities that could lead to increased STEM self-efficacy and STEM abilities did not make an explicit connection to the STEM concepts presented, as a result, STEM literacy may not occur. Overall the curricula failed to meet the outcomes as outlined in the National 4-H STEM Logic Model. To ensure that Utah 4-H continues to offer quality positive youth development programs it is recommended that Utah 4-H developed STEM resources review and address the outcomes of the 4-H STEM Logic Model and align more closely with the Next Generation Science Standards. While guidelines developed by National 4-H for curricula development are available to states for the planning, assessing, and evaluation the ability of the tools to address STEM requirements should be examined. Tools intended for 4-H STEM programs were developed in 2007 for the purpose of providing 4-H professionals and volunteers were with a consistent framework that guides designing, implementing, and evaluating 4-H SET (STEM) programming at local, state, and national levels (4-H, 2007). However, the STEM framework evaluation tools are no longer available (possibly lost) via personal communication with Tara Wheeler, 4-H Director of Learning Products (personal communication, Tara Wheeler, February 2017), meaning there is a need to develop a STEM curriculum framework.

These types of tools are necessary to produce and evaluate existing and future Utah 4-H STEM curricula in addition to volunteer development as 4-H SET program is aligned with the NSES/NGSS standards and focuses “on nonformal experientially-based delivery methods that address science abilities (process) and science anchors (content) in a hands-on way under the guidance of a trained (scientifically able) 4-H learning facilitator” (4-H, 2007, p. 3) in order to ensure that quality and effectiveness of 4-H SET (now 4-H STEM) programming. These methods will aid in the development and design of effective STEM curricula and meeting the goal for 4-H SET programs to develop and deliver content that is contextually valid to youth in a number of settings that addresses the needs of youth from diverse backgrounds (4-H, 2007).

Curriculum development is a fundamental piece of the 4-H Science Framework. If 4-H STEM curricula is to be effective in increasing knowledge, skills, interest and competencies and improve their attitude toward science, engineering and technology an expansive selection of 4-H STEM curricula that meets NSES/NGSS and the criteria in the curricula review process established by the National 4-H Headquarters (4-H, 2007) must be redeveloped and accessible. This system of research and evaluation designed to measure the effectiveness of 4-H STEM goals and objectives is a critical component of the 4-H Science Framework (4-H, 2007). To accomplish the goals and objectives of the 4-H STEM program, an infrastructure that prepares teams of youth and adults to aid in the design and evaluate 4-H STEM curricula must be implemented.

### **STEM Self-Efficacy**

The Utah 4-H STEM curricula that provided activities that addressed self-

efficacy, specifically, *Discover 4-H Code Clubs, Forces of Nature, Geology, Kitchen Science, and Robotics* were resources the showing the highest frequency for STEM self-efficacy with every activity providing youth with hands-on STEM activities. The sources of STEM self-efficacy were identified as open-ended questions and in hands-on activities that required youth to create, draw, build, observe, and discuss STEM related subjects on a beginner level but provided no suggestions for adapting activities to account for the ages and stages of youth receiving the instruction. In the 242 presented across all 13 curricula 179 of the activities addressed STEM self-efficacy (74%). These results suggest a strength in the 4-H STEM curricula for self-efficacy.

### **STEM Abilities**

STEM self-efficacy is acquired as youth experience success within activities that build STEM abilities. Activities that increase STEM abilities are linked to curricula that provides hands-on STEM activities that require youth to make predictions, use tools, and apply mathematic concepts. The Utah 4-H STEM curricula that provided opportunities for youth to acquire STEM abilities, specifically, *Fun-damental Science, An Unfortunate Camp, and the Magicians Laboratory* were the resources showing the highest frequency for STEM abilities. As illustrated by the frequency count, by providing youth with hands-on activities that required youth to make predictions, measure, observe, use tools, experiment, and test STEM related subjects. These activities present very basic STEM concepts on a beginner level and provide no suggestions for adapting activities to account for the ages and stages of youth receiving the instruction.

## **STEM Literacy**

STEM literacy is developed by activities where youth are given opportunities apply or demonstrate their abilities to remember, understand, analyze, evaluate, and create projects tied to real-world issues independently. Utah 4-H STEM curricula provided limited opportunities for youth build STEM literacy as most activities are identical and follow a chronological instructional pattern for completing projects. The Utah 4-H STEM curricula that provided opportunities for youth to demonstrate STEM literacy, specifically, *Fun-damental Science*, *An Unfortunate Camp*, and *the Magicians Laboratory* were the resources were the resources showing the highest frequency for STEM literacy. As illustrated by the frequency count, by providing youth with hands-on activities that required youth to make predictions, measure, observe, use tools, experiment, and test STEM related subjects. These activities present very basic STEM concepts on a beginner level and provide no suggestions for adapting activities to account for the ages and stages of youth receiving the instruction.

## **Recommendations for Further Study**

*Objective 2: Recommendations for a research-based rubric and template for the development of Utah 4-H STEM curricula.*

The results of this research demonstrate a need to create more STEM explicit curricula for out-of-school STEM programs, for example the Design Squad, which “provides activities and curricula guides to teach 9- to 12 -year-olds about engineering design. The focus areas—such as electricity, force, simple machines, and



transportation—include activities that allow students to build their own robots, circuits, games and more” (Afterschool Alliance, 2017, para 9). In addition, a collection of resources intended to provide 4-H science volunteer training were designed with the intention of training volunteers from a wide range of educational and professional backgrounds. Providing a blueprint for building an understanding of quality STEM programs, these resources expand the understanding of what educators should know about inquiry-based learning; further enhancing their knowledge of STEM concepts and positive youth development practices that frame 4-H STEM programming (National Research Council, 2015) thereby increasing the quality of after-school STEM programs America’s youth are receiving. 4-H is one out-of-school STEM provider that has focused on improving the capacity of its staff members to facilitate productive learning experiences.

Furthermore, a review of the process used by the 4-H National Headquarters vet curricula is also necessary. The development of nationally supported STEM curriculum is managed by the 4-H National Headquarters, within the U. S. Department of Agriculture’s (USDA) National Institute for Food and Agriculture (NIFA) and involves a diverse panel of Extension professionals who meet to evaluate proposed 4-H curriculum. Reviewers include 4-H youth development educators and specialists as well as other Extension professionals familiar with the field of youth development. Responsibilities of peer reviewers are as follows.

- Review curriculum/activities submitted within 2 weeks.
- Make recommendations based on how well the curriculum/activities meet the established criteria.

- Provide specific comments that will be returned to the author.
- Serve as a Peer Reviewer for a minimum of one year (maximum of two consecutive years). (4-H, 2016a)

Peer Reviewers must also have prior review experience, preferably on the state or national level. This includes:

- Reviews of conference workshops, grants, articles, evaluations, programs, curricula, or other review experience.
- Candidates must complete the web-based Curriculum Peer Reviewer training within two months of their application to become a curriculum peer reviewer.
- Candidates must complete the proper application materials. (4-H, 2016a)

In addition to selecting qualified persons to review curriculum submitted to National 4-H Headquarters for approval, reviewers need to have access to a 4-H Curriculum Lesson Plans Review Form (see Appendix F) developed by 4-H National Headquarters, NIFA, and the USDA to offer consistent guidelines in the review process. Utah 4-H has not adopted a process to ensure that STEM curricula is reviewed for the desired STEM outcomes related to STEM self-efficacy, STEM abilities, or STEM literacy.

These peer review methods are intended to maintain curriculum standards of quality, provide credibility, and ensure the integrity of 4-H youth curriculum and professional development materials (4-H, 2016a). This national level content building system serves as the outline for intentional learning experiences while building the competency and capacity of the 4-H program. The National 4-H organization has made their curriculum development tools available to assist writers creating activities based in 4-H experiential and inquiry learning methodology and encourages state and local 4-H

programs to use these resources for review purposes (4-H, 2016a).

Utah State University uses a review process called Fast Track to review curricula and fact sheets submitted by Extension professionals who are selected by the State 4-H Director based on their expertise. The guidelines used by reviewers to evaluate proposed 4-H curricula addresses *appropriateness* and grammatical, or style criteria. Of the 14 criteria only one asks about the *overall content*.

The resources created and used by the national 4-H curriculum peer review process and the Fast Track Process used by Utah4-H demonstrate a disparity between the standards used to validate proposed curricula for STEM programming. The national 4-H curriculum review process is available and accessible to State and local 4-H programs who are encouraged to use these resources for their own review purposes and needs clarification as to why Utah 4-H does not adhere to them. The development of Utah 4-H STEM curricula should require tools for planning and development and a formal evaluation to ensure that these are valid STEM resources. Moreover, reviewing the national standards outlined by NGSS, ITEEA, and CCSS for Mathematics curricula design and evaluation process will provide additional criteria in which existing and future Utah 4-H developed STEM curricula could be analyzed to determine if the curricula is valid in promoting STEM learning.

In conclusion, Utah 4-H should be applying the findings of this study to revise its existing STEM curricula and future STEM curricula. First, it is suggested that Utah 4-H should require learning activities contained within Utah 4-H STEM curricula to include two or more of the STEM subjects, as outlined by the National Science Teachers

Association in which concepts are coupled with real-world lessons as youth apply science, technology, engineering, and mathematics in contexts that make personal, local, and global connections (Gerlach, 2012, para 2). Second, Utah 4-H should create a research based rubric for the evaluation of state produced STEM curricula to ensure the validity and quality of its STEM programming and should include the following components which were adapted from the National Agricultural Literacy Curriculum Matrix Rubric for Lesson Plans to provide an example:

- Grade level/s targeted
- National 4-H STEM Logic Model outcomes that will be met through the objectives of the activities
- Content standards that meet the NSES/NGSS standards
- Purpose of the activity
- Estimated time it will take to complete the activity
- A list of the materials necessary to complete the activity
- Vocabulary words and the associated definitions related to the objectives of the activity
- Interest approach in the form of a question or discussion of an item that stimulates student
- Background (STEM connections which align with NGSS) which provides volunteers with a brief background necessary to effectively implement the activity
- An outline of the instructional procedures that follows the 5 E's instructional model (Engage, Explore, Explain, Elaborate, and Evaluate) and is presented through the 4-H experiential-based model, "*Do, Reflect, Apply*" where Do= engage/explore, Reflect= explain/elaborate, and Apply= evaluate/demonstrate
- Illustrations or content that is essential to the activity
- Links to sources/additional resources that support the objectives of the activity

- STEM facts that enhance or increase interest in the activity
- Extension activities that build a deeper understanding of the activity objectives
- References (National Agricultural Literacy Curriculum Matrix Rubric for Lesson Plans, n.d)

Third, Utah 4-H should develop a uniform template for the creation of STEM curricula based off of the requirements of the rubric, and finally Utah 4-H should implement meaningful trainings which include state developed STEM curricula as well as other STEM resources being used in Utah 4-H STEM programs for professionals and volunteers overseeing STEM programs.

These measures will ensure that first, state produced STEM curricula meets the national standards for STEM education. Second, thorough evaluations of the curricula are conducted thereby increasing the quality and validity of Utah 4-H STEM curricula. Third, provide a uniform format that will serve as a guide for those tasked with the development of existing and future Utah 4-H STEM curricula, and finally, professional and volunteer development for those overseeing STEM programs are receiving training that uses the nationally developed 4-H resources in addition to hands-on training in which participants experience and implement 4-H STEM curricula will lead to the effective delivery of STEM concepts contained within the curricula.

## REFERENCES

- 4-H. (2007). *4-H science, engineering and technology: A strategic framework for progress*. Document in possession of Dr. Spielmaker, Utah State University, Logan, UT.
- 4-H. (2010). Logic Models 4-H Professional Development. Retrieved June 08, 2017, from <http://4-h.org/professionals/professional-development/logic-models/>
- 4-H. (2016a). Curriculum development. Retrieved June 10, 2017, from <http://4-h.org/professionals/curriculum-development/#!/review>
- 4-H. (2016b). 4-H STEM & Agriculture Programs for Youth. Retrieved June 09, 2017, from <http://4-h.org/parents/stem-agriculture/>
- 4-H. (2016c). What is 4-H? Retrieved June 08, 2017, from <http://4-h.org/about/what-is-4-h/>
- 4-H. (2016d). 4-H Youth Programs at a Glance-Science, Health, Agriculture & Citizenship. Retrieved June 09, 2017, from <http://4-h.org/parents/programs-at-a-glance/>
- 4-H Science Program Design. (2013). *4-H science checklist*. Retrieved from <http://urban4hscience.rutgers.edu/practices/4h-science/science-checklist.html>
- Afterschool Alliance. (2017). *Curriculum and activities*. Retrieved from <http://www.afterschoolalliance.org/STEM-curriculum.cfm>
- Anderson, A. (2005). *An introduction to theory of change*. Retrieved from <http://www.hfrp.org/evaluation/the-evaluation-exchange/issue-archive/evaluation-methodology/an-introduction-to-theory-of-change>
- Anderson, L. W., & Krathwohl, D. R. (2001). *A taxonomy for learning, teaching, and assessing: A revision of Bloom's taxonomy of educational objectives*. New York, NY: Longman.
- Bandura, A. (1994). Self-efficacy. In V. S. Ramachaudran (Ed.), *Encyclopedia of human behavior* (Vol. 4, pp. 71-81). New York, NY: Academic Press. (Reprinted in H. Friedman [Ed.], *Encyclopedia of mental health*. San Diego: Academic Press, 1998).
- Berg, B. L. (2009). *Qualitative research methods for the social sciences*. Boston, MA: Pearson Education.

- Center for Theory of Change. (2016). *What is theory of change?* Retrieved from <http://www.theoryofchange.org/what-is-theory-of-change/>
- English, L. D. (2016). STEM education K-12: Perspectives on integration. *International Journal of STEM Education*, 3(1). doi: 10.1186/s40594-016-0036-1
- Fraenkal, J. R., Wallen, N. E., & Hyun, H. H. (2012). Content analysis. In M. Ryan, B. Mejia, A. McNamara, V. Malinee, V. Brien, S. Kiefer, & R. S. Colrey (Eds.), *How to design and evaluate research in education* (8<sup>th</sup> ed., pp. 477-504). New York, NY: McGraw-Hill.
- Gerlach, J. (2012). *STEM: Defying a simple definition*. Retrieved from <http://www.nsta.org/publications/news/story.aspx?id=59305>
- Hendricks, P. A. (1998). *Developing youth curriculum using the targeting life skills model: Incorporating developmentally appropriate learning opportunities to assess impact of life skill development*. Ames IA: Iowa State University, University Extension.
- Hidden curriculum. (2014, August 26). In S. Abbott (Ed.), the glossary of education reform. Retrieved from <http://edglossary.org/hidden-curriculum>
- Horton, B., Gogolski, J., & Warkentien, C. (2007). *Science, engineering, and technology (SET): Programming in the context of 4-H Youth Development*. Columbus, OH: The Ohio State University.
- Housel, A. (2015). A visual representation of three-dimensional learning: A tool for evaluating curriculum. *Science Scope*, 39(1), 58-62.
- Hussar, K., Schwartz, S., Bioselle, E., & Noam, G. (2008). *Toward a systematic evidence-base for science in out-of-school time*. Retrieved from [http://www.peecworks.org/PEEC/PEEC\\_Inst/01796300-001D0211.0/Hussar%20et%20al%202008%20Assessment%20of%20Science%20OST.pdf](http://www.peecworks.org/PEEC/PEEC_Inst/01796300-001D0211.0/Hussar%20et%20al%202008%20Assessment%20of%20Science%20OST.pdf)
- Technology for All Americans Project, & International Technology Education Association. (2007). *Standards for technological literacy: Content for the study of technology*. Reston, VA: International Technology Education Association.
- Jolly, A. (2014). *Six characteristics of a great STEM lesson*. Retrieved from [http://www.edweek.org/tm/articles/2014/06/17/ctq\\_jolly\\_stem.html](http://www.edweek.org/tm/articles/2014/06/17/ctq_jolly_stem.html)
- Jolly, J. L. (2009). Historical perspectives: The national defense education act, current STEM initiative, and the gifted. *Gifted Child Today*, 32(2), 50-53.
- Koonce, D. A., Zhou, J., Anderson, C. D., Hening, D. A., & Conley, V. M. (2011). *What is STEM?* Washington DC: American Society for Engineering Education.

- Krathwohl, D. R. (2002). A revision of Bloom's taxonomy: An overview. *Theory into practice*, 41(4), 212-218.
- Kress, C. (2014). Transformational education: The 4-H legacy. *Reclaiming Children and Youth*, 23(3), 5-9
- Kulm, G., Roseman, J. E., Treistman, M. 1999. A benchmarks-based approach to textbook evaluation. *Science Books & Films*, 35(4), 147-153.
- Langdon, D., McKittrick, G., Beede, D., Khan, B., & Doms, M. (2011). *STEM: Good jobs now and for the future* (ESA Issue Brief# 03-11). Washington, DC: U.S. Department of Commerce.
- Locklear, E. L. (2013). *4-H science initiative from inception to impact*. Chevy Chase, MD: The National 4-H Council.
- McKee, S. (2014). *Using word clouds to present your qualitative data*. Retrieved from <https://www.surveygizmo.com/survey-blog/what-you-need-to-know-when-using-word-clouds-to-present-your-qualitative-data/>
- McNaught, C., & Lam, P. (2010). Using Wordle as a supplementary research tool. *The Qualitative Report*, 15(3), 630-643. Retrieved from <http://nsuworks.nova.edu/tqr/vol15/iss3/8>
- Mielke, M., LaFleur, J., Butler, A., & Sanzone, J. (2013). *4-H science initiative: Youth engagement, attitudes, and knowledge study*. Retrieved from <http://3t61of1t6u3x3af7ir2y91ib.wpengine.netdna-cdn.com/wp-content/uploads/2016/02/Year-3-YEAK-Full-Report.pdf>
- National Agriculture in the Classroom. (2017). *National agricultural literacy curriculum matrix rubric for lesson plans*. Retrieved from [https://www.agclassroom.org/teacher/matrix/pdf/Lesson\\_Rubric.pdf](https://www.agclassroom.org/teacher/matrix/pdf/Lesson_Rubric.pdf)
- National Research Council. (1996). *National science education standards*. Washington, DC: National Academies Press.
- National Research Council. (2011). *Successful K-12 STEM education: Identifying effective approaches in science, technology, engineering, and mathematics*. Washington, DC: National Academies Press.
- National Research Council. (2012). *A framework for K-12 science education: Practices, crosscutting concepts, and core ideas*. Washington, DC: National Academies Press.



- National Research Council. (2015). *Identifying and Supporting Productive STEM Programs in Out-of-School Settings*. Washington, DC: The National Academies Press.
- National Science Teachers Association - NSTA. (2016, December). *NSTA position statement: The next generation science standards*. Retrieved from <http://www.nsta.org/about/positions/ngss.aspx>
- Newberry, P., & Kueker, D. (2008). *How do you recognize a rigorous and relevant curriculum? A method for analyzing rigor and relevance in science and mathematics curricula*. Retrieved from <http://www.vivayic.com>
- Next Generation Science Standards. (2013). *Next generation science standards: For states, by states*. Washington, DC: The National Academies Press.
- Persaud-Sharma, D. (2013). Pedagogical methods to promote STEM literacy. *The International Journal of Science, Mathematics and Technology Learning*, 19(4), 1-12. doi:10.18848/2327-7971/cgp/v19i04/49014
- QSR International. (2017). *What is NVivo*. Retrieved from <http://www.qsrinternational.com/what-is-nvivo>
- Rittmayer, A. D., & Beier, M. E. (2008). *Overview: Self-efficacy in STEM*. Retrieved from [http://www.engr.psu.edu/awe/misc/arps/arp\\_selfefficacy\\_overview\\_122208.pdf](http://www.engr.psu.edu/awe/misc/arps/arp_selfefficacy_overview_122208.pdf)
- Successful STEM Education. (2016, February 1). *Teaching and learning under the next generation science standards*. Retrieved from <http://successfulstemeducation.org/resources/teaching-and-learning-under-next-generation-science-standards>
- Trammell, A. (2014). *Using voyant tools for basic text analysis*. Retrieved from <https://publish.illinois.edu/commonsknowledge/2014/10/10/using-voyant-tools-for-basic-text-analysis/>
- U.S. Department of Education. (n.d.). *Science, technology, engineering and math: Education for global leadership*. Retrieved from <http://www.ed.gov/stem>
- Utah 4-H. (n.d.). *Bugs! A creepy, crawly adventure*. January from <http://utah4h.org/staffresources/stemcampguides/>
- Utah 4-H. (2009). *Fun-damental science*. Retrieved from <http://utah4h.org/staffresources/stemcampguides/>
- Utah 4-H. (2011a). *An unfortunate camp*. Retrieved from <http://utah4h.org/staffresources/stemcampguides/>

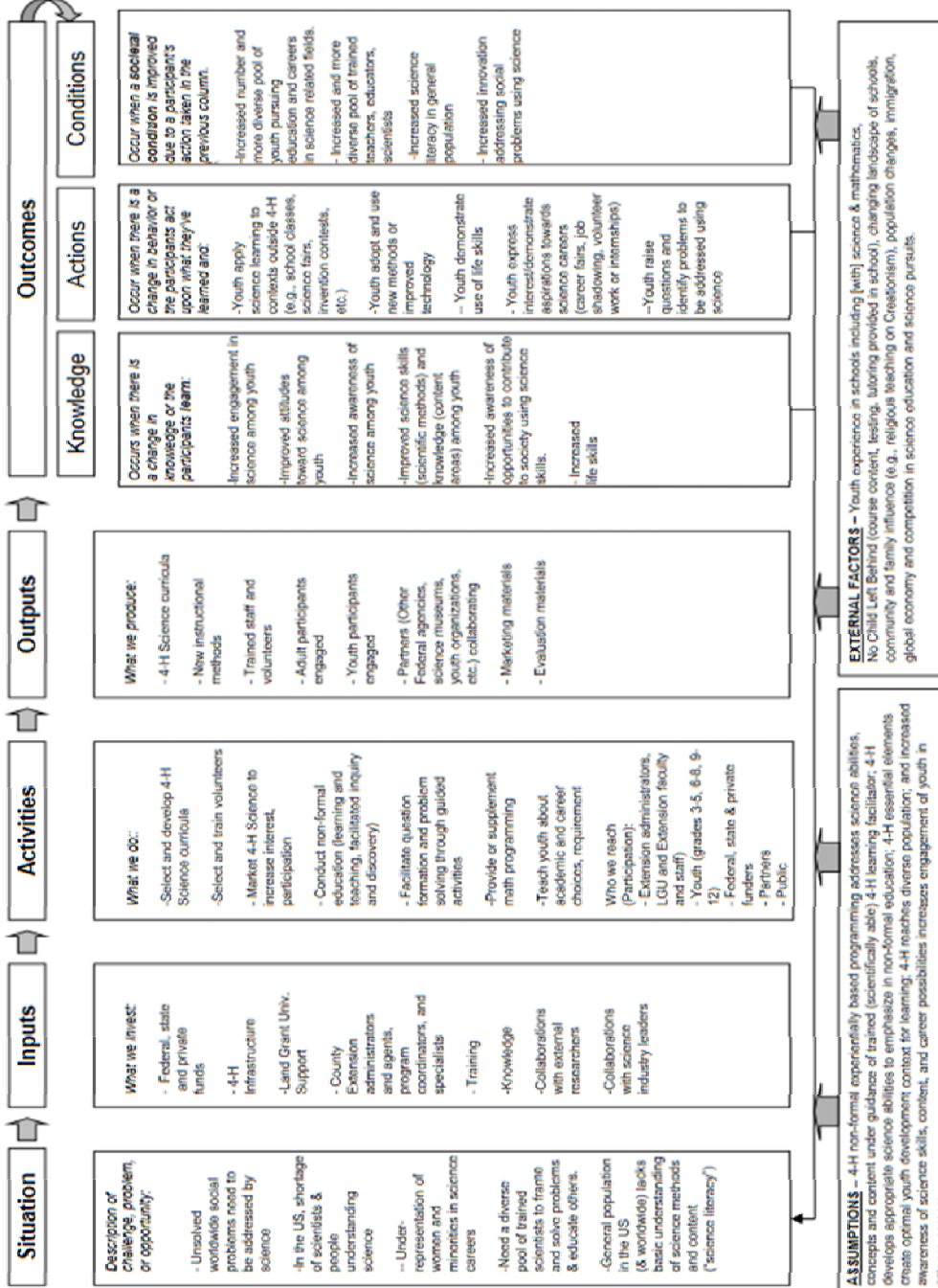
- Utah 4-H. (2011b). *4-H multi-family club*. Retrieved from <http://utah4h.org/staffresources/stemcampguides/>
- Utah 4-H. (2016a). *STEM*. Retrieved from <http://utah4h.org/projects/stem/>
- Utah 4-H. (2016b). *STEM camp guides*. Retrieved June 08, 2017, from <http://utah4h.org/staffresources/stemcampguides/>
- U.S. Department of Education. (2015). *Science, technology, engineering and math: Education for global leadership*. Retrieved from <http://www.ed.gov/stem>
- U.S. Department of Education, Office of Innovation and Improvement. (2016). *STEM 2026: A vision for innovation in STEM education*. Washington, DC: Author.
- White, D. W. (2014). What is STEM education and why is it important? *Florida Association of Teacher Educators Journal*, 1(14), 1-9.
- You for Youth. (n.d.). *STEM literacy*. Retrieved from <http://dev1.y4y.seiservices.com/learn/stem/introduction/stem-literacy>

APPENDICES

Appendix A

4-H Science Logic Model

### 4-H Science Logic Model



Note: 4-H Science encompasses science, engineering, technology and applied math.

Updated November 1, 2010

Appendix B

Utah 4-H Peer Review Questions

## Utah 4-H Peer Review Questions

1. Does the submission present useful and current information?
2. Do you believe the submission is appropriate for USU Extension publication?
3. Does the author(s) provide current research-based evidence in support of the information and conclusions presented in the fact sheet?
4. Additional comments on question #3:
5. Is the contribution of the proposed submission:
6. How would you rate the overall content of the proposed submission under review?
7. Is the proposed submission title suitable?
8. If no, can you suggest a more suitable title?
9. Does the author(s) appropriately use tables and figures to support the information and conclusions presented in the submission?
10. If no, please provide suggestions on how tables or figures could be improved.
11. Are the references appropriate, containing in-text citations and a reference list? Do the submission references conform to the style used in the Journal of Extension (<http://www.apastyle.org/>)
12. Is the submission written at the appropriate technical level for targeted clientele group?
13. What is the overall quality of the submission?
14. Recommendation for publication:
15. Please add any other comments here.

Appendix C

STEM Self-Efficacy Code Book



## STEM Self-Efficacy Code Book

STEM Self-Efficacy	Source
Hands-on	UCANR-Experiential Learning Check-off List
Open-ended questions that invite discussion and interaction	UCANR-Experiential Learning Check-off List
Inquiry-based (acquisition of knowledge and skills through exploration that requires rational powers, reasoning, and process skills)	UCANR-Experiential Learning Check-off List
Opportunities to reflect on experience by sharing with others	UCANR-Experiential Learning Check-off List
Opportunities to discuss how experience was carried out, discuss problems, issues, and recurring themes	UCANR-Experiential Learning Check-off List
Discuss problems	UCANR-Experiential Learning Check-off List
Discuss issues	UCANR-Experiential Learning Check-off List
Discuss recurring themes	UCANR-Experiential Learning Check-off List
Opportunities to make connections between the activity and real-world examples are evident	UCANR-Experiential Learning Check-off List
Concepts are formulated and terms are introduced/discovered through or after experience	UCANR-Experiential Learning Check-off List
Plan learning activities that actively engage them in learning – build, create, explore, make, discover, test, plan, cut, estimate, experience, measure, draw, etc.	Illinois 4-H Volunteer Quick Guide
Present them with a challenge or problem to solve. Encourage and support them, but allow them to discover the solution.	Illinois 4-H Volunteer Quick Guide
Provide leadership opportunities such as, leading an activity, helping others who need assistance, or planning a family event to showcase what members have learned.	Illinois 4-H Volunteer Quick Guide
Provide opportunities for members to share what they have learned, created, and mastered at a family event, competition, or community gathering.	Illinois 4-H Volunteer Quick Guide
When things don't work out as planned, talk with the young person and ask what s/he thinks went wrong, what s/he could do differently, and how to avoid the mistake in the future. Allow the young person to reflect on the experience, share his/her thoughts, and identify a solution.	Illinois 4-H Volunteer Quick Guide

STEM Self-Efficacy	Source
Laboratory work	Rittmayer/Beier <a href="http://www.engr.psu.edu/awe/misc/arps/arp_selfefficacy_overview_122208.pdf">http://www.engr.psu.edu/awe/misc/arps/arp_selfefficacy_overview_122208.pdf</a>
Experiments	Rittmayer/Beier <a href="http://www.engr.psu.edu/awe/misc/arps/arp_selfefficacy_overview_122208.pdf">http://www.engr.psu.edu/awe/misc/arps/arp_selfefficacy_overview_122208.pdf</a>
Design Projects	Rittmayer/Beier <a href="http://www.engr.psu.edu/awe/misc/arps/arp_selfefficacy_overview_122208.pdf">http://www.engr.psu.edu/awe/misc/arps/arp_selfefficacy_overview_122208.pdf</a>
applied activities	Rittmayer/Beier <a href="http://www.engr.psu.edu/awe/misc/arps/arp_selfefficacy_overview_122208.pdf">http://www.engr.psu.edu/awe/misc/arps/arp_selfefficacy_overview_122208.pdf</a>
Hands-on exercises	Rittmayer/Beier <a href="http://www.engr.psu.edu/awe/misc/arps/arp_selfefficacy_overview_122208.pdf">http://www.engr.psu.edu/awe/misc/arps/arp_selfefficacy_overview_122208.pdf</a>
Building	Rittmayer/Beier <a href="http://www.engr.psu.edu/awe/misc/arps/arp_selfefficacy_overview_122208.pdf">http://www.engr.psu.edu/awe/misc/arps/arp_selfefficacy_overview_122208.pdf</a>
Programming	Rittmayer/Beier <a href="http://www.engr.psu.edu/awe/misc/arps/arp_selfefficacy_overview_122208.pdf">http://www.engr.psu.edu/awe/misc/arps/arp_selfefficacy_overview_122208.pdf</a>
Dissecting	Rittmayer/Beier <a href="http://www.engr.psu.edu/awe/misc/arps/arp_selfefficacy_overview_122208.pdf">http://www.engr.psu.edu/awe/misc/arps/arp_selfefficacy_overview_122208.pdf</a>
Assigned a real-world problem	Rittmayer/Beier <a href="http://www.engr.psu.edu/awe/misc/arps/arp_selfefficacy_overview_122208.pdf">http://www.engr.psu.edu/awe/misc/arps/arp_selfefficacy_overview_122208.pdf</a>
Required to structure problem resolution	Rittmayer/Beier <a href="http://www.engr.psu.edu/awe/misc/arps/arp_selfefficacy_overview_122208.pdf">http://www.engr.psu.edu/awe/misc/arps/arp_selfefficacy_overview_122208.pdf</a>
Set proximal goals	Rittmayer/Beier <a href="http://www.engr.psu.edu/awe/misc/arps/arp_selfefficacy_overview_122208.pdf">http://www.engr.psu.edu/awe/misc/arps/arp_selfefficacy_overview_122208.pdf</a>
Create action plan	Rittmayer/Beier <a href="http://www.engr.psu.edu/awe/misc/arps/arp_selfefficacy_overview_122208.pdf">http://www.engr.psu.edu/awe/misc/arps/arp_selfefficacy_overview_122208.pdf</a>
Work to solve problem	Rittmayer/Beier <a href="http://www.engr.psu.edu/awe/misc/arps/arp_selfefficacy_overview_122208.pdf">http://www.engr.psu.edu/awe/misc/arps/arp_selfefficacy_overview_122208.pdf</a>
Repairing	Rittmayer/Beier <a href="http://www.engr.psu.edu/awe/misc/arps/arp_selfefficacy_overview_122208.pdf">http://www.engr.psu.edu/awe/misc/arps/arp_selfefficacy_overview_122208.pdf</a>

STEM Self-Efficacy	Source
Feedback (constructive)	Rittmayer/Beier <a href="http://www.engr.psu.edu/awe/misc/arps/arp_selfefficacy_overview_122208.pdf">http://www.engr.psu.edu/awe/misc/arps/arp_selfefficacy_overview_122208.pdf</a>
Rewards	Rittmayer/Beier <a href="http://www.engr.psu.edu/awe/misc/arps/arp_selfefficacy_overview_122208.pdf">http://www.engr.psu.edu/awe/misc/arps/arp_selfefficacy_overview_122208.pdf</a>
Teamwork	Rittmayer/Beier <a href="http://www.engr.psu.edu/awe/misc/arps/arp_selfefficacy_overview_122208.pdf">http://www.engr.psu.edu/awe/misc/arps/arp_selfefficacy_overview_122208.pdf</a>
Group activities	Rittmayer/Beier <a href="http://www.engr.psu.edu/awe/misc/arps/arp_selfefficacy_overview_122208.pdf">http://www.engr.psu.edu/awe/misc/arps/arp_selfefficacy_overview_122208.pdf</a>
Observation of others engaged in activity	Rittmayer/Beier <a href="http://www.engr.psu.edu/awe/misc/arps/arp_selfefficacy_overview_122208.pdf">http://www.engr.psu.edu/awe/misc/arps/arp_selfefficacy_overview_122208.pdf</a>

Appendix D  
STEM Abilities Code Book

### STEM Abilities Code Book

STEM Abilities	Source
Analyze	4-H SET Abilities
Build	4-H SET Abilities
Categorize	4-H SET Abilities
Classify	4-H SET Abilities
Collaborate	4-H SET Abilities
Collect Data	4-H SET Abilities
Communicate	4-H SET Abilities
Compare	4-H SET Abilities
Construct	4-H SET Abilities
Contrast	4-H SET Abilities
Demonstrate	4-H SET Abilities
Design Solutions	4-H SET Abilities
Draw	4-H SET Abilities
Evaluate	4-H SET Abilities
Graph	4-H SET Abilities
Hypothesize	4-H SET Abilities
Implement Solutions	4-H SET Abilities
Infer	4-H SET Abilities
Interpret	4-H SET Abilities
Invent Solutions	4-H SET Abilities
Measure	4-H SET Abilities
Model	4-H SET Abilities
Observe	4-H SET Abilities
Optimize	4-H SET Abilities
Order	4-H SET Abilities
Organize	4-H SET Abilities
Plan Investigations	4-H SET Abilities
Predict	4-H SET Abilities
Problems Solve	4-H SET Abilities
Question	4-H SET Abilities
Reason	4-H SET Abilities
Redesign	4-H SET Abilities
Research a problem	4-H SET Abilities

STEM Abilities	Source
State a Problem	4-H SET Abilities
Summarize	4-H SET Abilities
Test	4-H SET Abilities
Troubleshoot	4-H SET Abilities
Use Numbers	4-H SET Abilities
Use Tools	4-H SET Abilities
Unifying concepts and processes in science.	NSES, 1997
Science as inquiry.	NSES, 1997
Physical science.	NSES, 1997
Life science.	NSES, 1997
Earth and space science.	NSES, 1997
Science and technology.	NSES, 1997
Science in personal and social perspectives.	NSES, 1997
History and nature of science.	NSES, 1997
Systems	NSES, 1997
Order	NSES, 1997
Organization	NSES, 1997
Evidence	NSES, 1997
Models	NSES, 1997
Explanation	NSES, 1997
Change	NSES, 1997
Constancy	NSES, 1997
Measurement	NSES, 1997
Evolution	NSES, 1997
Equilibrium	NSES, 1997
Form	NSES, 1997
Function	NSES, 1997
Scientific inquiry	NSES, 1997
Ability to distinguish between natural objects and objects made by humans K-4	NSES, 1997
Abilities of technological design K-12	NSES, 1997
Understanding about science and technology K-12	NSES, 1997
Represents a central event or phenomenon in the natural world.	NSES, 1997
Represents a central scientific idea and organizing principle.	NSES, 1997
Has rich explanatory power.	NSES, 1997

STEM Abilities	Source
Guides fruitful investigations.	NSES, 1997
Applies to situations and contexts common to everyday experiences.	NSES, 1997
Can be linked to meaningful learning experiences.	NSES, 1997
Is developmentally appropriate for students at the grade level specified	NSES, 1997
The concepts and processes provide connections between and among traditional scientific disciplines	NSES, 1997
The concepts and processes are fundamental and comprehensive	NSES, 1997
The concepts and processes are understandable and usable by people who will implement science programs.	NSES, 1997
The concepts and processes can be expressed and experienced in a developmentally appropriate manner during K-12 science education	NSES, 1997
Ask a question about objects, organisms, and events in the environment	NSES, 1997
Plan and conduct a simple investigation	NSES, 1997
Employ simple equipment and tools to gather data and extend the senses	NSES, 1997
Use data to conduct a reasonable explanation	NSES, 1997
Communicate investigations and explanations	NSES, 1997
Identify a simple problem	NSES, 1997
Propose a solution	NSES, 1997
Implementing proposed solutions	NSES, 1997
Evaluate a product or design	NSES, 1997
Communicate a problem, design, and a solution	NSES, 1997
Identify questions that can be answered through scientific investigations	NSES, 1997
Design and conduct a scientific investigation	NSES, 1997
Use appropriate tools and techniques to gather, analyze, and interpret data	NSES, 1997
Develop descriptions, explanations, predictions and models using evidence	NSES, 1997
Think critically and logically to make the relationship between evidence and explanations	NSES, 1997
Recognize and analyze alternative explanations and predictions	NSES, 1997
Communicate scientific procedures and explanations	NSES, 1997
Use mathematics in all aspects of scientific inquiry	NSES, 1997
Different kinds of questions suggest different kinds of scientific investigations. Some investigations involve observing and describing objects, organisms, or events; some involve collecting specimens; some involve experiments; some involve seeking more information; some involve discovery of new objects and phenomena; and some involve making models.	NSES, 1997
Current scientific knowledge and understanding guide scientific investigations. Different scientific domains employ different methods, core theories, and standards to advance scientific knowledge and understanding.	NSES, 1997

STEM Abilities	Source
Mathematics is important in all aspects of scientific inquiry.	NSES, 1997
Technology used to gather data enhances accuracy and allows scientists to analyze and quantify results of investigations.	NSES, 1997
Scientific explanations emphasize evidence, have logically consistent arguments, and use scientific principles, models, and theories. The scientific community accepts and uses such explanations until displaced by better scientific ones. When such displacement occurs, science advances.	NSES, 1997
Science advances through legitimate skepticism. Asking questions and querying other scientists' explanations is part of scientific inquiry. Scientists evaluate the explanations proposed by other scientists by examining evidence, comparing evidence, identifying faulty reasoning, pointing out statements that go beyond the evidence, and suggesting alternative explanations for the same observations.	NSES, 1997
Scientific investigations sometimes result in new ideas and phenomena for study, generate new methods or procedures for an investigation, or develop new technologies to improve the collection of data. All of these results can lead to new investigations.	NSES, 1997
Asking questions (for science) and defining problems (for engineering)	NGSS 2013
Developing and using models	NGSS 2013
Planning and carrying out investigations	NGSS 2013
Analyzing and interpreting data	NGSS 2013
Using mathematics and computational thinking	NGSS 2013
Constructing explanations (for science) and designing solutions (for engineering)	NGSS 2013
Engaging in argument from evidence	NGSS 2013
Obtaining, evaluating, and communicating information	NGSS 2013
Ask questions about what would happen if a variable was changed	NGSS 2013
Identify scientific (testable) and non-scientific (non-testable) questions	NGSS 2013
Ask questions that can be investigated and predict reasonable outcomes based on patterns such as cause and effect relationships	NGSS 2013
Use prior knowledge to describe problems that can be solved	NGSS 2013
Define a simple design problem that can be solved through the development of an object, tool, process, or system and includes several criteria for success and constraints on materials, time, or cost.	NGSS 2013



Appendix E

Bloom's Taxonomy Action Verbs

## REVISED Bloom's Taxonomy Action Verbs

Definitions	I. Remembering	II. Understanding	III. Applying	IV. Analyzing	V. Evaluating	VI. Creating
<b>Bloom's Definition</b>	Exhibit memory of previously learned material by recalling facts, terms, basic concepts, and answers.	Demonstrate understanding of facts and ideas by organizing, comparing, translating, interpreting, giving descriptions, and stating main ideas.	Solve problems to new situations by applying acquired knowledge, facts, techniques and rules in a different way.	Examine and break information into parts by identifying motives or causes. Make inferences and find evidence to support generalizations.	Present and defend opinions by making judgments about information, validity of ideas, or quality of work based on a set of criteria.	Compile information together in a different way by combining elements in a new pattern or proposing alternative solutions.
<b>Verbs</b>	<ul style="list-style-type: none"> <li>• Choose</li> <li>• Define</li> <li>• Find</li> <li>• How</li> <li>• Label</li> <li>• List</li> <li>• Match</li> <li>• Name</li> <li>• Omit</li> <li>• Recall</li> <li>• Relate</li> <li>• Select</li> <li>• Show</li> <li>• Spell</li> <li>• Tell</li> <li>• What</li> <li>• When</li> <li>• Where</li> <li>• Which</li> <li>• Who</li> <li>• Why</li> </ul>	<ul style="list-style-type: none"> <li>• Classify</li> <li>• Compare</li> <li>• Contrast</li> <li>• Demonstrate</li> <li>• Explain</li> <li>• Extend</li> <li>• Illustrate</li> <li>• Infer</li> <li>• Interpret</li> <li>• Outline</li> <li>• Relate</li> <li>• Rephrase</li> <li>• Show</li> <li>• Summarize</li> <li>• Translate</li> </ul>	<ul style="list-style-type: none"> <li>• Apply</li> <li>• Build</li> <li>• Choose</li> <li>• Construct</li> <li>• Develop</li> <li>• Experiment with</li> <li>• Identify</li> <li>• Interview</li> <li>• Make use of</li> <li>• Model</li> <li>• Organize</li> <li>• Plan</li> <li>• Select</li> <li>• Solve</li> <li>• Utilize</li> </ul>	<ul style="list-style-type: none"> <li>• Analyze</li> <li>• Assume</li> <li>• Categorize</li> <li>• Classify</li> <li>• Compare</li> <li>• Conclusion</li> <li>• Contrast</li> <li>• Discover</li> <li>• Dissect</li> <li>• Distinguish</li> <li>• Divide</li> <li>• Examine</li> <li>• Function</li> <li>• Inference</li> <li>• Inspect</li> <li>• List</li> <li>• Motive</li> <li>• Relationships</li> <li>• Simplify</li> <li>• Survey</li> <li>• Take part in</li> <li>• Test for</li> <li>• Theme</li> </ul>	<ul style="list-style-type: none"> <li>• Agree</li> <li>• Appraise</li> <li>• Assess</li> <li>• Award</li> <li>• Choose</li> <li>• Compare</li> <li>• Conclude</li> <li>• Criteria</li> <li>• Criticize</li> <li>• Decide</li> <li>• Deduct</li> <li>• Defend</li> <li>• Determine</li> <li>• Disprove</li> <li>• Estimate</li> <li>• Evaluate</li> <li>• Explain</li> <li>• Importance</li> <li>• Influence</li> <li>• Interpret</li> <li>• Judge</li> <li>• Justify</li> <li>• Mark</li> <li>• Measure</li> <li>• Opinion</li> <li>• Perceive</li> <li>• Prioritize</li> <li>• Prove</li> <li>• Rate</li> <li>• Recommend</li> <li>• Rule on</li> <li>• Select</li> <li>• Support</li> <li>• Value</li> </ul>	<ul style="list-style-type: none"> <li>• Adapt</li> <li>• Build</li> <li>• Change</li> <li>• Choose</li> <li>• Combine</li> <li>• Compile</li> <li>• Compose</li> <li>• Construct</li> <li>• Create</li> <li>• Delete</li> <li>• Design</li> <li>• Develop</li> <li>• Discuss</li> <li>• Elaborate</li> <li>• Estimate</li> <li>• Formulate</li> <li>• Happen</li> <li>• Imagine</li> <li>• Improve</li> <li>• Invent</li> <li>• Make up</li> <li>• Maximize</li> <li>• Minimize</li> <li>• Modify</li> <li>• Original</li> <li>• Originate</li> <li>• Plan</li> <li>• Predict</li> <li>• Propose</li> <li>• Solution</li> <li>• Solve</li> <li>• Suppose</li> <li>• Test</li> <li>• Theory</li> </ul>

Appendix F  
4-H Curriculum Evaluation

## 4-H Curriculum Evaluation

Submission Date	
Lead Submitter	
Submitter's Email/Phone	
Submitter's University	
Name of Other Submitters	
Title	
Single Lesson or Series of Lessons	<input type="radio"/> Single Lesson <input type="radio"/> Series of Lessons
Primary Content Area of Lesson (s)	<input type="radio"/> Citizenship <input type="radio"/> Healthy Living <input type="radio"/> Science <input type="radio"/> Youth/Volunteer Development <input type="radio"/> Professional Development
Funding Source	
Review Date	

<b>Submission Information</b>	<b>Reviewer Scores &amp; Comments</b>
-------------------------------	---------------------------------------

**Implementation Guidance**

Checklist of implementation guidance. <ul style="list-style-type: none"> <li><input type="radio"/> Length of Time</li> <li><input type="radio"/> Materials Needed (if any)</li> <li><input type="radio"/> Safety Precautions Identified (if needed)</li> <li><input type="radio"/> Purpose Statement Provided</li> <li><input type="radio"/> National Educational Standard Identified (or linked to)</li> </ul>	Appropriate implementation guidance is provided for each activity. <ul style="list-style-type: none"> <li><input type="radio"/> Pass</li> <li><input type="radio"/> Fail</li> </ul>
---	---

**Target Audience**

Indicate the target audience for this material. <ul style="list-style-type: none"> <li>• Lower Elementary (K-2)</li> <li>• Upper Elementary (3-5)</li> <li>• Middle School/Junior High (6-8)</li> <li>• High School (9-12)</li> <li>• Collegiate (Undergraduate)</li> <li>• Adult Volunteer</li> <li>• 4-H Volunteer</li> <li>• General Public</li> </ul>	The content is appropriate for the target audience. <ul style="list-style-type: none"> <li><input type="radio"/> Pass</li> <li><input type="radio"/> Fail</li> </ul>
---	--

**Quality Content**

<p>Checklist of quality content standards.</p> <ul style="list-style-type: none"> <li>• Content is current</li> <li>• Content is relevant</li> <li>• Content is research based</li> <li>• Content is accurate</li> </ul>	<p>The content meets quality standards as appropriate. (Not all standards are appropriate for every format.)</p> <ul style="list-style-type: none"> <li>○ Pass</li> <li>○ Fail</li> </ul>
--	---

**Learning Method**

<p>One or more of the following learning methods is clearly utilized.</p> <ul style="list-style-type: none"> <li>• Experiential learning</li> <li>• Inquiry Based Learning</li> <li>• Life Skills Development</li> </ul>	<p>Learning method (s) for each activity is appropriate for the content. One or more of the following learning styles is clearly utilized.</p> <ul style="list-style-type: none"> <li>○ Pass</li> <li>○ Fail</li> </ul>
--	---

**Learning Style**

<p>One or more of the following learning styles is clearly utilized.</p> <ul style="list-style-type: none"> <li>• Visual</li> <li>• Auditory</li> <li>• Tactile</li> </ul>	<p>Learning style (s) for each lesson is appropriate for the content. If a series of lessons, each style is used at least once in the series.</p> <ul style="list-style-type: none"> <li>○ Pass</li> <li>○ Fail</li> </ul>
--	--

**Positive Youth Development**

<p>Checklist of key positive youth development standards and principles.</p> <ul style="list-style-type: none"> <li>• Lesson engage the learner</li> <li>• Lessons are culturally and ethnically sensitive</li> <li>• Lessons incorporate one or more of the essential elements (belonging, mastery, independence, generosity)</li> </ul>	<p>Positive youth development standards and principles are met in each lesson. If a series of lessons, each essential element is used at least once in the series.</p> <ul style="list-style-type: none"> <li>○ Pass</li> <li>○ Fail</li> </ul>
---	---

**References Documented**

<p>Shows evidence of crediting original sources and receiving copyright permissions as appropriate.</p>	<p>References are appropriately documented.</p> <ul style="list-style-type: none"> <li>○ Pass</li> <li>○ Fail</li> </ul>
---	--

#### 4- H Name & Emblem

<p>Checklist of key 4-H Name &amp; Emblem standards.</p> <ul style="list-style-type: none"> <li>• Emblem is used in its entirety</li> <li>• Emblem is not distorted, flipped, angled or otherwise altered from its upright position</li> <li>• Emblem stem points to the right</li> <li>• No image or text is placed under, over or otherwise obscures the emblem</li> <li>• The color of the emblem follows official guidelines</li> <li>• The emblem does not imply endorsement of any product or material</li> </ul>	<p>Material meets 4-H Name &amp; Emblem graphic standards and guidelines.</p> <ul style="list-style-type: none"> <li>○ Pass</li> <li>○ Fail</li> <li>○ Not Applicable (3<sup>rd</sup> party vendor submission)</li> </ul>
---	---

#### Presentation of Information

<p>Checklist of presentation standards.</p> <ul style="list-style-type: none"> <li>• Correct spelling, grammar, and punctuation</li> <li>• Coherent flow of information and ideas</li> <li>• Images and graphics (if used) are easily read, contribute to the content and inclusive in depiction</li> </ul>	<p>The information in each lesson meets presentation standards.</p> <ul style="list-style-type: none"> <li>○ Pass</li> <li>○ Fail</li> </ul>
---	--

#### Learning Strategies

<p>Checklist of key learning strategies for professional development standards and principles.</p> <ul style="list-style-type: none"> <li>• Activities are based on sound learning theory</li> <li>• Learners are provided the opportunity to assess their current level of knowledge</li> <li>• Learners are provided the opportunity to give input into the learning process</li> <li>• Accessibility issues are addressed so that learners may fully engage</li> </ul>	<p>Professional development standards and principles are met in each lesson.</p> <ul style="list-style-type: none"> <li>○ Pass</li> <li>○ Fail</li> </ul>
---	---

**Learning Application**

<p>Checklist of key strategies for applying professional development learning.</p> <ul style="list-style-type: none"> <li>• Opportunities for collaboration and problem solving are evident.</li> <li>• Opportunities that challenge learners and connect them to real-life problems are provided</li> <li>• Techniques that will encourage learners to transfer knowledge gain to behavior change are provided.</li> </ul>	<p>Opportunities and techniques to apply learning strategies are met in each lesson.</p> <ul style="list-style-type: none"> <li>○ Pass</li> <li>○ Fail</li> </ul>
---	---

**Overall Rating**

<ul style="list-style-type: none"> <li>○ PASS: This Curriculum has passed all review criteria.</li> <li>○ FAIL: This Curriculum does not pass all review criteria.</li> </ul>
---

**General Comments (from Reviewer to Submitter)**

--