STEM education in Virginia 4-H: A qualitative exploration of engineering understandings in 4-H STEM educators

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GENERAL AUDIENCE ABSTRACT

In 2007, 4-H made a specific commitment to improve Science, Technology, Engineering, and Mathematics (STEM) literacy in America's youth by forming the 4-H Science mission mandate. However, research suggests in order for educators to successfully implement STEM programming, they need to understand the content and best teaching practices, which presents a unique obstacle for 4-H educators as many lack formal education in both. By conducting interviews with current 4-H educators in Virginia, this research begins to highlight the importance behind STEM understanding and STEM teaching practices – particularly as they pertain to engineering projects. These interview and data analysis process uncovered common themes including connections between engineering and current 4-H educational approaches, as well as the existing barriers between volunteers as STEM educators and successful programming. In order to improve STEM education within 4-H, professional development strategies focusing on engineering characteristics, outcomes aligning with 4-H goals, and applications to real-world problems should be implemented.

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ACADEMIC ABSTRACT

Science, Technology, Engineering, and Mathematics (STEM) education is spurred by an economic and social need for cross-discipline understanding of complex, worldwide problems, made through intentional connections between two or more STEM subject areas. In order for educators to articulate these connections, research suggests they must have a firm understanding of the individual disciplines through both content and pedagogical approaches. In 2007, as a leader in non-formal STEM education, 4-H made a specific commitment to improve STEM literacy in America's youth by forming the 4-H Science mission mandate, therefore increasing its STEM programming.

This qualitative study examined how 4-H educators come to understand STEM and engineering concepts and utilizations, and whether their backgrounds influence their verbalization or expectations of engineering. Narrative themes emerged that help determine how engineering is currently and can continue to be more clearly and consistently articulated and connected within 4-H programming. Themes included 1) a lack of direct connection or understanding of engineering characteristics to 4-H programs, 2) familiarity with and ability to apply engineering characteristics to the Do Reflect Apply model, and 3) the importance of volunteers as STEM and engineering educators within 4-H programming.

Strategies for professional development emphasizing engineering understandings, learning outcomes, and broad applications were discovered. Professional development should consider the effects of engineering and STEM self-efficacy, as well as professional identity

development. Additionally, it utilize approaches such as the Do Reflect Apply model, and reflect on the learning objectives 4-H educators strive to achieve during STEM programming in conjunction with life-skills.

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Chapter 1: Introduction

Background and Setting

Science, Technology, Engineering, and Mathematics (STEM) education is supported by an economic and social need for cross-discipline understanding of complex, worldwide problems. While multiple understandings of STEM education are realistically utilized in both formal and non-formal education (Bybee, 2010), most common definitions articulate that STEM education is two or more subject areas taught throughout one instructional unit (Laboy-Rush, 2011; Sanders, 2009; Wells, 2015; Zollman, 2012) with intentional connections between the subjects discussed and demonstrated (Sanders, 2009; Wells, 2015). However, it is common for students to lack the ability to make these connections on their own, therefore requiring the assistance of an educator to clearly define the relationships between these content areas (Agustin, et al., 2012; Heibert & Lefevre, 1986). In order for educators to articulate these connections, they must possess a firm understanding of the individual disciplines through both content and pedagogical approaches.

Statement of the Problem

Challenges for Engineering Understanding in STEM 4-H Programming

4-H as a youth education initiative Every year, 4-H engages with over six million youth between the ages of 5-19 in urban, suburban, and rural areas through programming and mentorship by adult educators and volunteers (Worker and Mahacek, 2013). 4-H demonstrates the role of out-of-school-time, non-formal programs by encouraging youth to excel through hands-on engagement (Worker and Mahacek, 2013). Since its inauguration in 1902, the 4-H Youth Development Program, administered by the USDA specifically through land-grant universities, showcases a history of youth development towards engagement with science, engineering, technology, nutrition, leadership, and citizenship education (Worker and Mahacek, 2013).

4-H science initiatives In 2007, as a leader in non-formal technology, engineering, and science education, 4-H made a specific commitment to improve STEM literacy in America's youth by forming the 4-H Science mission mandate (Worker and Mahacek, 2013; 4-H, 2007). This National 4-H Science Initiative developed efforts to concentrate 4-H programming on teaching science, technology, engineering, and applied mathematics (Mielke, LaFleur, Butler, & Sanzone, 2013). Though a desired outcome of the programs would be to address the critical need for engineers and scientists in the workforce (Worker and Mahacek, 2013), 4-H recognized that the preparation of youth in STEM disciplines would not be accomplished simply through career competencies as rocket scientists or computer programmers; it would be accomplished through 21st century skills that encourage logical, organized, and systematic solutions to wicked problems (Kennedy & Odell, 2014; Shinn et al., 2003).

This initiative focused on the formation of non-formal, out-of-school-time science programming for youth based on experiential learning, inquiry based methods, and positive youth development (Worker and Mahacek, 2013). The goals of these programs are to address the critical need for a larger number of scientists and engineers within the workforce. The outcomes expected through this initiative include:

> (a) knowledge gains among youth--increased awareness of science; improved science, engineering, and technology skills and knowledge; and increased life skills; (b) a change in youth behavior--youth apply science, engineering, and technology learning to contexts outside of 4-H; youth adopt and use new methods or improved technology; and youth express aspirations towards STEM careers;

and (c) long-term societal impact--increased number and more diverse pool of youth pursuing education and careers in STEM fields; and increased scientific literacy in the general population (Worker and Mahacek, 2013).

Intentional STEM Infusion (Elliott-Engel, Robinson, & Westfall-Rudd, 2019), and other integrated STEM curriculum, have helped introduce intentional connections by requiring the facilitator and/or volunteer to identify STEM problems and activities in the project work. However, application of an interdisciplinary STEM curriculum is not always effectively implemented in non-formal educational programs, including the 4-H Youth Development Program, where few of the educational agents are trained in engineering – a discipline that is less often content driven and rather an overarching approach to solving a problem. This lack of formal education is potentially compounded when 4-H educators are not confident in understanding engineering in a broader sense, therefore less likely to verbally emphasize the connections between engineering and STEM activities. This misalignment between necessary facilitation of STEM connections and specialized engineering content knowledge is cause for concern. Without understanding what engineering is or how engineering works, STEM education may not be reaching its full potential in 4-H programming.

Purpose

The findings of this research will provide a window into how 4-H educators articulate engineering through a prominent STEM activity. It will also begin to determine where 4-H educators came to understand engineering concepts and utilizations, and whether this background influences the verbalization or expectations of engineering understandings. Through this window, strategies for professional development emphasizing engineering understandings and broad applications may become known. While only a small-scale study, narrative themes can be investigated further and refined to better determine how engineering can be more clearly and consistently articulated and connected within STEM 4-H programming.

Research Questions

Based on available literature and theoretical frameworks, a lack of specialized engineering content knowledge and engineering self-efficacy within 4-H educators may result in an unbalanced understanding and verbal identification of engineering connections to STEM programming.

In order to learn about the understandings and articulations of engineering within 4-H educators, the following research questions focused on strategies and applications of knowledge presented in a STEM focused program were considered:

1. How do 4-H educators see engineering integrated within the 4-H STEM curriculum, projects, or programming?
2. What characteristics of engineering are emphasized as important in the teaching of engineering within the 4-H curriculum, projects, or programming, and why are these characteristics important?
3. How did these 4-H educators, through formal or informal training, influence, student interest, or other, come to utilize these characteristics to describe or discuss engineering?

Theoretical Framework

Specialized Content Knowledge

While 4-H's model of experiential learning known as 'Do. Reflect. Apply.' Closely aligns with Kolb's (1984) model of learning encouraging continual reflection to promote expanded thinking and context application, it cannot be fully utilized without content knowledge. In previous studies, researchers have looked at what an educator needs to know in order to teach a content area. Broadly speaking, this general approach to understanding content knowledge originating with Shulman in 1986 has since been divided into subdomains including 'Subject Matter Knowledge' (SMK), or the content necessary to teach, and 'Pedagogical Content Knowledge' (PCK), or the teaching practices necessary to teach. SMK has then further been split into 'Common Content Knowledge' (CCK), 'Specialized Content Knowledge' (SCK), and 'Horizon Content Knowledge' (HCK).

Extensive research has been conducted in the field of mathematics to determine the importance of both mathematics content knowledge and pedagogical content knowledge (Ball, Hill, & Bass, 2005; Ball, Thames, & Phelps, 2008; Cai, Mok, Reddy, & Stacey, 2016; Hattie & Donoghue, 2016; Krainer, Hsieh, Peck, & Tatto, 2015; Silverman & Thompson, 2008). In engineering, however, research has focused on PCK meaning that the content knowledge necessary to teach engineering has taken a backseat to the pedagogical approaches that can effectively communicate engineering. This lack of research specific to engineering content knowledge is at the detriment of the field as "PCK is inconceivable without a substantial level of CK [subject knowledge]" (Baumert et al., 2010, p. 163), suggesting that subject content knowledge is essential and therefore must proceed PCK (e.g., Cai et al., 2016; Krainer et al., 2015). Closely related to SCK is Common Content Knowledge (CCK), with the difference being in the utilization of the knowledge. CCK is knowledge used in a wide variety of settings, while SCK is specific to the knowledge necessary to teach (Ball et. al, 2008). Furthermore, SCK includes procedural and conceptual understandings and the ability for the educator to recognize errors that commonly occur from the students (Ball et al., 2008; Ball, Thames, Bass, Sleep, Lewis, & Phelps, 2009), as well as the skill and understanding to analyze student interactions, provide clarification, and utilize suitable imagery for concept representation (Hill, Rowan, &

Ball, 2005). Therefore, a professional engineer need not give reason behind multiple iterations of the design process that result in optimization of a solution for a particular set of parameters, but this reasoning is necessary for an educator engaging with specialized engineering content knowledge in education.

While a specific SCK model does not exist for engineering content, the utilization of the framework developed by Lin, Chin and Chiu (2011) gives a solid guideline for implementation. They suggest that SCK is made of three components: representation, justification, and explanation. For engineering contexts, this would require the educator 1) choose and use the representation of engineering effectively and accurately, 2) describing and justifying engineering considerations and ideas, and 3) offer explanation of the process and procedures through common engineering practices.

Representations refer to both internal organization of knowledge as well as the external representations including real-world contexts, models, or expressions of engineering (Ipek, 2018). Explanation and justification then develop the meaningful higher-level learning by requiring students to express deep understanding and justification of thought (Schwarz, Hershkowitz & Prusak, 2010; Yackel & Hanna, 2003). For SCK to fully be realized, all three components should be satisfied, as it is not possible to solve a problem without inclusion of justification or usage of representations (Ipek, 2018).

While a formal list of SCK characteristics has not yet been developed for engineering, these same ideas can be applied to engineering understanding when used in conjunction with the commonly accepted and articulated engineering design process. These include 1) defining the problem, 2) doing background research, 3) determining criteria and constraints, 4) brainstorming, evaluating, and choosing a solution, 5) developing a prototype, 6) testing the solution, 7) communicate results and redesign. Additionally, based upon expert panel discussion of engineering design, characteristics such as complex, iterative, ill-defined, process-organization, flexibility, and constraints pertaining to nature, economic, market, and legislation are engineering understood characteristics (Maier and Storrle, 2011), though this list is not all-inclusive.

Self-Efficacy

Since its introduction in Bandura's 1977 theory of social learning, self-efficacy has been highly utilized as a measurement within education. The concept of self-efficacy is "belief in one's capabilities to organize and execute the sources of action necessary to manage prospective situations" (Bandura, 1986). This concept has been heavily applied to educators as research indicates a relationship between self-efficacy and those teachers' behaviors, many of which affect student performance (Coladarci, 1992; Gibson & Dembo, 1984; Muijs & Reynolds, 2002). Self-efficacy affects whether a person decides to take part in an endeavor, how much effort is put into that action, whether the person's thoughts aid or hinder the self, stress or discomfort experienced during these activities, and whether the action is seen as accomplished (Bandura, 1997). Tschannen- Moran, Woolfolk Hoy, and Hoy (1998) furthered this understanding by suggesting that the initial performance of a task is affected by the original self-efficacy, which the success or failure of that initial performance becoming the new level of teaching self-efficacy. This finding suggests that if low self-efficacy already exists within an educational environment, it will continue to cycle within that programming, potentially leading to a lack of goal formation, teaching aspirations, and future motivation and achievement surrounding engineering (Bandura, 1997; Bandura, 1986).

While models and instruments have been developed for the measurement of teach self-efficacy, most are designed for global assessment and therefore may not produce practice specific information (Tschannen-Moran, Woolfolk Hoy, and Hoy, 1998). Since 2012 with the addition of engineering practices to K-12 science curriculum (NRC, 2012), there has been an increased interest in engineering teaching self-efficacy, which lead to the development of the Teaching Engineering Self-Efficacy scale (TESS) developed and validated by Yoon Yoon, Evans, and Strobel (2012). While this instrument has been further validated and integrated into research studies measuring teacher self-efficacy (Yoon Yoon, Evans, & Strobel, 2014), and other efforts have considered engineering design self-concept (Carberry, Lee, & Ohland, 2010), these were not utilized directly in this study. Rather, this research began the first look at what and how 4-H educators currently understanding engineering, with potential further self-efficacy studies suggested.

This study therefore strives to break apart the understanding of 4-H educators teaching STEM and engineering focused projects by utilizing the SCK framework proposed by Lin et al. (2011) for knowledge assessment and self-efficacy as a component of engineering education.

Limitations and Research Subjectivity

Time is a limitation of this study as interviews were conducted independent of the relative frequency of engagement with STEM education programming. Data collection is also limited to interviews which do not allow for qualitative validity between reported and observed activity.

Qualitative research is a study of the lived experience, with the researcher positioned as the filter for data organization and synthesis. As the researcher, I am therefore positioned within the study. I have both a bachelors and masters degree in engineering with experience teaching

STEM curriculum in a variety of non-formal arenas. This experience will provide me with content knowledge of engineering applications to real-world problems and industrial needs. Care will be taken prior to data collection and analysis to address the bias points of view inherent to my personal lived experiences and understandings.

Definition of Terms

STEM Education is two or more subject areas taught throughout one instructional unit with intentional connections between the subjects discussed and demonstrated.

Engineering is the art of making practical applications of pure knowledge towards the formation of a problem that can be solved through construction and evaluation of design.

Chapter 2: Review of Literature

The importance of STEM education

In 1983, A Nation at Risk was published by the U.S. Government, describing how education systems were failing to create and support students literate in science, math, and technology (Gardner & Larsen, 1983). However, true interest in the fields of science, technology, engineering, and math was not fully considered until the 1990s in the United States (Kelley and Knowles, 2016). Motivated by a lapse in global economic advancement (Friedman, 2005), funding for STEM education and research (Sanders, 2009) created an urgent need for education reform within the following twenty years (AAAS, 1989, 1993; ABET, 2004; ITEA, 1996, 2000, 2002, 2007; NCTM, 1989, 2000; NRC, 1989, 1994, 1996, 2012).

With these efforts, however, came critiques from education professionals as competing agendas and theories muddled the complexity of STEM integration into educational curriculum, particularly within K-12 applications (Kelley and Knowles, 2016). Reforms including Next Generation Science Standards (NGSS) (NGSS Lead State, 2013) support intentional integration of STEM disciplines by cross-connecting the STEM fields more effectively. Publications such as STEM Integration in K-12 Education: Status, Prospects, and an Agenda for Research (NAE and NRC, 2014) have identified issues such as lack of coherent effort, as well as identification and instruction of intersections for the integration of STEM as roadblocks currently limiting STEM education. In order to rectify some of these problems, the Committee on Integrated STEM Education began identifying and classifying successful approaches that integrate STEM, review assessment of student learning impacts, and finally produce priorities within STEM education research. While this effort created a common language, there is still work to be done to fully integrate STEM into formal and non-formal utilization (NAE and NRC, 2014).

Ultimately, the importance of STEM education continues today. Most notably, wicked problems, such as over-population, climate change, agricultural production, resource management, declining energy and water sources, require increased competencies in technology and science to fully access and improve these cross-disciplinary issues (Thomas and Watters, 2015). However, studies have indicated that motivation and interests in STEM learning have decreased, specifically in western countries (Thomas and Watters, 2015). This creates continued concern for many nations as the need for STEM skills in order to sustain economic stability and global security increases (English, 2016; Marginson, Tytler, Freeman, & Roberts 2013; NAE and NRC, 2014; Kelley and Knowles, 2016). Additionally, research suggests it is necessary for youth to develop understandings around STEM before and throughout early education through their innate interest (NRC, 2007; Maltese & Tai, 2010), which can lead to increased involvement in STEM learning later in life (NRC, 2011). 4-H, as an organization focused on youth development in a broad contexts of setting, is positioned to uniquely and significantly influence future STEM interactions.

STEM education shortcomings One major concern compounding STEM education is the ambiguity involved with effective utilization (Breiner, Harkness, Johnson, & Koehler, 2012). While a majority of the literature communicates STEM as an interdisciplinary effort, most projects or programs teach each discipline in a disconnected manor (Abell and Lederman, 2007; Sanders, 2009; Wang, Moore, Roehrig, & Park, 2011). For example, science and mathematics literacy are commonly assessed in isolation (Breiner et al., 2012; Sanders, 2009; Wang et al., 2011) with a lack of connection with or through engineering or technology (Bybee, 2010; Hoachlander and Yanofsky, 2011). Moore, Stohlmann, Wang, Tank, Glancy, and Roehrig (2014) described STEM integration as “an effort to combine some or all of the four disciplines of science, technology, engineering, and mathematics into one class, unit, or lesson that is based on connections between the subjects and real-world problems" (p. 38). STEM content learning objectives can therefore come from one subject, but context integration can belong within another STEM subject (Moore et al., 2014). Sanders (2009) provides another definition of STEM integration as "approaches that explore teaching and learning between/among any two or more of the STEM subject areas, and/or between a STEM subject and one or more other school subjects" (p. 21). This definition suggests that learning outcomes are produced from at least one STEM subject, but that technology or engineering design should be the contextualized platform (Sanders, 2009). Finally, Kelley and Knowles (2016) define integrated STEM education as "the approach to teaching the STEM content of two or more STEM domains, bound by STEM practices within an authentic context for the purpose of connecting these subjects to enhance student learning" (p. 3). This approach acknowledges some previous mathematics and sciences skills are necessary, engineering design may force a focus on career pathways that limit authenticity, and that current technology may act as an inherent barrier to creative expansion (Kelley and Knowles, 2016).

Strategic approaches are necessary to fully integrate STEM subjects. Curriculum exhibiting this integration allows students to learn about stimulating and relevant experiences, inspires improves critical thinking skills, advances problem-solving abilities, and improves retention (Stohlmann, Moore, & Roehrig, 2012). Furthermore, the utilization of scientific inquiry and quantitative reasoning through formulation and investigation of questions can be linked with engineering design processes to solve STEM related problems (Kennedy et al., 2004; Robinson, 2017), potentially providing a platform through which to encourage the identified outcomes of critical thinking and problem solving. It is common for students to lack the ability to make these connections on their own, therefore requiring the assistance of an educator to clearly define the relationships between these content areas (Agustin, et al., 2012; Heibert & Lefevre, 1986). In general, most research supports the communication of STEM integration through themes (Foutz, Navarro, Bill, Thompson, Miller & Riddleberger, 2011; Hansen & Gonzalez, 2014; Sahin & Top, 2015), though others focus more heavily on the utilization of the design process to intentionally discuss STEM connections (Sanders, 2009).

Models for STEM education utilization As STEM education has become increasingly prevalent, educators have begun to integrate theories of learning by doing, or experiential learning, into the platform. Since STEM education can be aimed at teaching, in context, math, science, and engineering concepts through integrative instruction with a focus on technology, multiple integrative, practical theories have been proposed to better understand the components and relationships within STEM curriculum.

For example, the Massachusetts Department of Education (2006) utilizes a Venn diagram intersecting science, engineering and technology. From this model, science "seeks to understand the natural world", engineering uses "scientific discoveries to design products and processes", and technology is "the result of the engineered design" (Massachusetts Department of Education, 2006, p. 81). While each can stand alone, they can each also intersect with one other component. The center section, were all three content areas function under one societal need or want, is theoretically where authentic STEM learning occurs. Worker and Mahacek (2013) expand on this relationship by contending that mathematics supports science, technology, and engineering and acts as a primary language for all three.

Other models, including Kelley and Knowles (2016) focus on the integrated STEM approach by viewing the individual content areas as part of a larger pulley system, surrounded by a rope signifying a community of practice. This model emphasizes that each of the four STEM disciplines must work in tandem to produce an entire system; however, each component does not need to be present in all STEM activities, but rather must be relationally understood and be applied across domains by the educator. Ultimately, this integrated approach is thought to more effectively increase problem solving skills, encourage higher level critical thinking, create opportunities for stimulating experiences, and improve retention (Stohlmann et al, 2012).

Regardless of the exact conceptual framework utilized, Becker and Park (2011) analyzed 28 studies that assessed integrative STEM approaches, with data suggesting improvements in overall achievements for students in the integrated curriculum. However, further research is needed to understand the learning necessary for these connections, as well as the understanding and previous knowledge of those facilitating the STEM education curriculum.

STEM Self-Efficacy

In order for educators to accurately and effectively articulate any of the previously outlined STEM models or approaches, they must be knowledgeable on STEM concepts and addressing misunderstandings of STEM from youth (Ginns & Watters, 1995). For STEM curriculum, educators are required to have a broader content knowledge surrounded by a systems thinking perspective (NRC, 2011) – a challenge given the historic separation between disciplines throughout K-12 education. These issues, when coupled with the idea that educators are more likely to teach what they have previously learned (Deemer, 2004; Llinares & Krainer, 2006), potentially lead to low confidence educators with limited STEM preparation to lead STEM projects or programs (Skamp & Mueller, 2001; Yates & Chandler, 2001). This low level of comfort and confidence surrounding STEM curriculum – often referred to as STEM self-efficacy – can matriculate throughout the educational system.

Efficacy has been shown to influence the motivation, enthusiasm, and time an educator spends or embodies within a topic, leading to the success or failure of student learning (Settlage, Southerland, Smith, & Ceglie, 2009; Tschannen-Moran, Woolfold Hoy, & Hoy, 1998). Research suggests that efficacy is excessively importance within STEM contexts (Zeldin, Britner, & Pajares, 2008) and elementary educators (Brand & Wilkins, 2007), with Zeldin, et al. (2008) specifically explored self-efficacy and influences surrounding men and women's STEM academic and career choices. Factors influencing efficacy and confidence for educators within STEM curriculum specifically included professional development opportunities, educational experience, and preparation of the curriculum by the educator (Jarrett, 1999). Ultimately, confidence and knowledge in STEM contexts are likely interconnected (Harlen & Holroyd, 1997), meaning that low knowledge can not only lead to low efficacy, but that this low efficacy can also result in misconceptions surrounding STEM concepts (Schoon & Boone, 1998). This discrepancy is important to consider for any educational research wishing to further understand educator practices and utilizations around STEM programming.

While STEM self-efficacy is an issue that must be considered, research suggests that STEM curriculum is most effectively taught to youth through active, inquiry based, authentic applications (NRC, 2000; NSTA, 2002). While current literature does not appear to take this claim further, it might suggest that STEM curriculum can be effectively taught without mastery of each content area when the teaching practices surrounding active, inquiry based, authentic applications are made. Further research is necessary to determine whether this claim might be accurate, and 4-H, with its focus on experiential, hands-on learning in connection to formal settings, offers an important platform for such integration.

The importance of non-formal, experiential learning

Approximately 95% of learning throughout a person's life occurs in out-of-school, non-formal settings such as organized programming, hobbies, museums, television, and other sources, with only 5% of learning occurring in the traditional classroom (Falk & Dierking, 2010). Additionally, educational goals focusing on learning the application of content instead of learning to know information have become increasingly important. Application of content can be showcased in a variety of avenues, though a strong development of practical know-how is often learned through "doing" (Fenwick, 2003), a component commonly integrated into non-formal programming. As a result, non-formal programs are prime to challenge students to utilize their minds and hands to solve engineering design problems through connections with real-world collaborations (NRC, 2009; Worker and Mahacek, 2013). Non-formal learning environments therefore offer a platform for experiential learning, which increase options and choices for learners to engage with their individual passions (Worker and Mahacek, 2013).

This idea of learning through experience is rooted in apprenticeship training through repeated practice, real-world contextualization of tools, as well as the dynamics of political and social atmosphere (Fenwick, 2003), though has evolved over the decades by heavily emphasizing learner-centered education (Knowles, 1970), reflection (Kolb, 1984), and perspective transformation (Mezirow, 1990, 1991, 1996). Given STEM education's need for some of these approaches, many non-formal education programs have integrated STEM curriculum into their initiatives.

4-H's non-formal education initiative to increase STEM

The increase in attention and funding for STEM education caused both formal and non-formal K-12 and postsecondary education faculties to concentrate on improvement of these curriculum and instructional areas (Basham & Marino, 2013; National Research Council, 2012). Youth development programs specifically focused on STEM integration efforts by increasing emphasis on projects such as robotics (Nugent, Barker, Grandgenett, & Welch, 2016; Riley & Butler, 2012). The 4-H Youth Development Program – America's largest youth development organization, facilitated by Cooperative Extension and focusing on learning through doing (What Is 4-H?, 2018) – was included in this push.

4-H experiential learning 4-H youth development has long relied on the program context of learning by doing or experiential learning. This strategy has many similarities to the steps needed to develop STEM literacy (Arnold, Bourdeau, & Nott, 2013), therefore presenting an ideal context in which to develop such programming. As such, 4-H educators should capitalize on the experiential learning model to promote STEM education in non-formal teaching and learning (Arnold, et al, 2013; Nugent, et al., 2016). The advantage of using experiential learning over experience alone is that youth participate in designed experiences that make a strong connection between real world and academic knowledge (Beard & Wilson, 2002). The experiential learning model has been imbued into 4-H club work with the 'Do. Reflect. Apply.' strategy based upon Kolb's (1984) argument that a person's thoughts and ideas are not fixed and that learning is a process.

In order to facilitate STEM utilization within a 4-H context, a 4-H Science Logic Model (2010) was created that outlined the inputs, activities, outputs, and outcomes associated with a STEM environment. The national 4-H organization also created a repository of resources of STEM program in non-formal environments for local and state 4-H staff that could provide effective STEM training to 4-H educators (Locklear, 2013). These resources were both designed to provide a blueprint from which to build understanding of quality STEM programs, regardless of the educational or professional backgrounds of the volunteers (Simmons dissertation, 2017). In a broader sense, this educational information enhanced the understanding of STEM concepts and inquiry-based learning that frame not only 4-H STEM programming, but general positive youth development practices as well (National Research Council, 2015), therefore improving the quality of non-formal STEM programs for youth. However, even with attempts to integrate science, math, and STEM content areas into education, specifically within an agricultural context (Blum, 1996; Stubbs & Myers, 2015; The National Council for Agricultural Education, 2015), educators still desire more training in order to successfully integrate these concepts into educational curriculum (Anderson & Anderson, 2012; Balschweid & Thompson, 2002; Thompson & Balschweid, 2000).

Engineering in STEM education

In order to achieve an in-depth understanding of 4-H engineering and STEM realizations, a review of empirical work regarding educator knowledge of engineering practices was first necessary. While most Americans have engaged with scientific inquiry, few have received any education on engineering and the differences between the two ideas of thought. Scientific inquiry requires the formation of a hypothesis (question) which can be “answered through investigation” (Kennedy and Odell, 2014, p. 247). Engineering design, however, “involves the formation of a problem that can be solved through constructing and evaluating during the post design stage” (Kennedy and Odell, 2014, p. 247). Design is often viewed as the engineering element that distinguishes engineering from other approaches to problem-solving (Dym, 1999; Dym, Agogino, Eric, Frey, and Leifer, 2005). Teaching design has been shown to increase the ability of students to foster social skills and learn core subjects (Goldman, 2002; Kolodner et al., 2003).

Regardless of these strengths, there is still a lack of engineering integration into STEM programming, particularly within agriculture, food, and natural resources.

Engineering is often viewed as the missing link that joins math and science skills and knowledge with technical and societal innovation (NCTL, 2015, “The Missing Piece”). Contemporary educational efforts, including the Next Generation Science Standards, vocalize a need for engineering to be taught as a platform for science education, as engineering design facilitates core science ideas through modeling, planning, interpreting and analyzing data, and creating justifications of outputs (NGSS Lead States, 2013). In practice, educators are unable to differentiate engineering and science (Antink-Meye & Meyer, 2016; Karatas, Micklos, & Bodner, 2011), suggesting that engineering is not being taught in addition to science and instead labeled within science and the scientific method. This finding is further supported by the finding that both engineering and technology are largely absent in STEM education literature within the agriculture, food, and natural resources realm (Scherer, McKim, Wang, DiBenedetto, & Robinson, in press). Both as an integrative tool and as a stand-alone content area, engineering is seldom the focus of STEM interests, even when the educational article discussed STEM throughout their efforts (Scherer et al., in press).

There are significant advantages for STEM programs that properly promote engineering design. For example, design requires a real-world context to be assessed, with these contexts allowing learners to apply important prior knowledge to a unique situation in an intuitive way (Koedinger & Nathan, 2004; Moore & Carlson, 2012). Engineering design also requires students to critically redesign, recreate, and rebuild after the initial iteration of their project. Critical thinking and reflection on what is known, and what is still needed to be learned, promotes a learner's metacognition (Turner, 2011; Zollman, 2012). Through engineering design approaches, learners are put in the center of the learning experience, allowing them to have opportunities to apply their thinking skills and to solve authentic problems in an authentic context.

4-H educator understandings of engineering

Research suggests that educators, in both formal and non-formal contexts, have difficulties fully grasping STEM components, resulting in little connection to engineering challenges (Bybee, 2010). Additionally, while many educators understand the importance of an interdisciplinary approach to STEM education, they are uncertain how this can be achieved (Leonard Gelfand Center for Service Learning and Outreach at Carnegie Mellon, 2008). As a result, most present math and science components as isolated entities, and some question whether engineering could be taught to younger students (Leonard Gelfand Center for Service Learning and Outreach at Carnegie Mellon, 2008). However, those who had integrated engineering into their programs observed an increased interest from their students to learn science and math concepts that would then allow them to redesign, recreate, or rebuild their projects (Leonard Gelfand Center for Service Learning and Outreach at Carnegie Mellon, 2008). Bybee (2010) specifically predicts that these misalignments with STEM education will exist until model STEM units, professional development, or STEM assessment are actively integrated into programming. While some effort has been made in proposing agendas for STEM integration (Honey, Pearson, & Schweingruber 2014; Robinson, 2017), a lack of research surrounding factors directly influencing interdisciplinary STEM integration constrict the potential advancement.

While engineering is not consistently considered an educational content area, it is a well-known career field. As such, engineering is likely perceived as having a degree of professional identity development, loosely understood as the professional process one experiences that allows for individual membership into a certain social community (Wenger, 1998). For engineers, this might be defined as a certain set of personal characteristics or knowledge, and is socially constructed via language and interactions with others (Hung, 2008). For new members of these communities, such as educators who do not have a formal background in engineering, their interactions with experienced engineers must incorporate their own personal identities (Wenger, 1998), suggesting that if an educator cannot relate to the unique characteristics or knowledge of an engineer, they may not see themselves as a member of that engineering community.

Potential improvements One approach that could improve STEM education literacy is specific professional development workshops. Nadelson, Callahan, Pyke, Hay, Dance & Pfiester, (2013) documented that K-5 elementary teachers exhibited improved perception, knowledge, and confidence in STEM projects. The professional development implemented in this case began with a 3-day summer institute for topic introduction including STEM curriculum development and inquiry instruction, as well as local and state educational standards in connection to STEM curriculum. Online modules were also used during the school year that continued to emphasize the inquiry based STEM approach taught within this study. Lastly, a university researcher would visit each teacher twice during the year to observe and provide feedback regarding implementation of the STEM lessons. While not within a STEM specific context, other research efforts including Ross & Bruce (2007) suggest an increase in self-efficacy with an increase in professional development.

However, professional development regrading engineering curriculum may not be enough to overcome structural and social understandings of engineering and engineering characteristics. As with many professional development workshops, Nadelson et al. (2013)'s approach was faced with challenges in recruitment, as well as reflection and refinement to incorporate long-term improvement. Another example of engineering professional development issues is Engineering is Elementary (EiE) – a leading advocate for engineering curriculum implementation – who host a variety of engineering professional development sessions where educators are encouraged to interact as students (Engineering is Elementary, n.d.). After the completion of these workshops, evaluations completed by the educators indicate an improved understanding of engineering, but still showed a low self-efficacy for implementation, suggesting that professional development alone may not significantly improve engineering programming (Engineering is Elementary, n.d.; Sargianis, Yan, & Cunningham, 2012). Once professional development changes were made that included college faculty as a bridge between EiE staff and preservice teachers, EiE again evaluated educator competencies and efficacy. Surprisingly, competencies in engineering did not significantly improve (only a 2% improvement pre- and post-professional development), but there was a significant improvement in self-efficacy and attitude towards engineering, suggesting that educator self-efficacy and competency might act independently of each other (Velthuis, Fisser, Pieters, 2014).

Rich, Jones, Belikov, Yoshikawa, and Perkins (2017) found similar results when assessing elementary educator self-efficacy for engineering and STEM content. They concluded that there was little difference in self-efficacy for science and math between educators who did and did not engage in their professional development, but that a significant difference occur when applied to engineering and technology (Rich et al., 2017). They also found that educators with backgrounds in STEM inherently held a higher self-efficacy (Rich et al., 2017). As such, it may be more important for engineering professional development efforts to focus less on whether or not 4-H educators understand engineering, but rather what their confidence and feelings towards engineering might be.

As organizations such as the National Research Council and Next Generation Science Standards encourage the integration of engineering into science, however, it is important to understand how educators conceptualize the differences and similarities between a defined K-12 content area (science) and a non-content area (engineering) (Honey et al., 2014), regardless of challenges presented through currently available literature. Without this initial understanding of the utilization of engineering in non-formal learning environments by the educators, further professional development or education initiatives are bound to fail.

Chapter 3: Methodology

Purpose

The findings of this research will provide a window into how 4-H educators articulate engineering through prominent STEM activities. It will also begin to determine where 4-H educators came to understand engineering concepts and utilizations, and whether this background influences the verbalization or expectations of engineering understandings. Through this window, strategies for professional development emphasizing engineering understandings and broad applications may become known. While only a small-scale study, narrative themes can be investigated further and refined to better determine how engineering can be more clearly and consistently articulated and connected within STEM 4-H programming.

Statement of the Problem

Based on available literature and theoretical frameworks, a lack of specialized engineering content knowledge and engineering self-efficacy within 4-H educators may result in an unbalanced understanding and verbal identification of engineering connections to STEM programming.

Research Questions

In order to learn about the understandings and articulations of engineering within 4-H educators, the following research questions focused on strategies and applications of knowledge presented in a STEM focused program were considered:

1. How do 4-H educators see engineering integrated within the 4-H STEM curriculum, projects, or programming?

2. What characteristics of engineering are emphasized as important in the teaching of engineering within the 4-H curriculum, projects, or programming, and why are these characteristics important?
3. How did these 4-H educators, through formal or informal training, influence, student interest, or other, come to utilize these characteristics to describe or discuss engineering?

Research Design

In order to answer the previously outlined questions relating to 4-H STEM programming and engineering implementation, the following qualitative methodology was implemented. Eleven educators of STEM curriculum from Virginia, having received traditional youth training from their respective 4-H system, were randomly selected for interviews. Criteria for the selection will be prior experience teaching STEM programming in both classroom and out-of-the-classroom settings. Participants will not be screened for educational background, location, years of experience, or professional development surrounding STEM or engineering as this metadata will be considered within the data collection and analysis for potential population generalization (Bailey, 2018).

All participants identified as female and were located throughout Virginia including low to high density counties. Years of experience varied from a couple of years to upwards of fifteen, though it was noted that some participants included experience as educators outside of the 4-H context when answer such questions. While all participants indicated previous participation in STEM professional development, a majority described this professional development as project based with an emphasis on what to teach within a specific STEM program application. Professional development for a majority of participants was not described as an opportunity to learn why or how to teach STEM under a broader understanding.

Educational backgrounds for the participants heavily included bachelor's degrees in science fields with a few participants having received a masters in science or a bachelors in a non-STEM field. No participants had completed a degree in engineering and only one indicated having taken an engineering based course on industrial organization. A slight majority reported they had received a formal degree in education and/or curriculum development, many as a requirement for continued employment within Virginia Cooperative Extension.

During recruitment, it was assumed that educators self-identified as teachers of STEM curriculum within 4-H. Since responsibilities of 4-H educators range from direct programming to administrative tasks, the researchers were unable to predict how heavily any participant might engage with STEM or engineering curriculum. It was assumed that this number would be greater than zero and that the agents would feel comfortable discussing these activities, their feelings, and involvement open and honestly.

Due to time and logistical constraints, not all 4-H agents engaging with STEM in Virginia could be included in this study. Additionally, research observations were not utilized in this study to validate or further assess the claims made by the agents, though this possibility is viewed as a potential future expansion on this research project. Also, based on the original study questions, volunteers who might lead or heavily interact directly with students were not included in this study. Inclusion of volunteers within future studies should be considered.

Data Collection Procedures

Once participants were recruited through snowball sampling (Bailey, 2018), video conference interviews were conducted that include a semi-structured, synchronous format with open-ended questions surrounding engineering understanding, engineering integration into STEM programming, and engineering implementation origins, as well as background educational information from the facilitator. Semi-structured formatting treated the question guide as a "living document" (pg. 107) and allowed for the "flow of the interview, rather than the order in the guide" (pg. 107) to dictate how and when the predetermined questions were asked (Bailey, 2018). Open-ended questions utilizing "what" and "how" phrases elicited thorough responses (Kvale, 1996) while synchronous video conferencing helped build rapport that "treats the respondent as an equal, allows him or her to express personal feelings, and therefore presents a more 'realistic' picture that can be uncovered" (Fontanta and Frey, 1994, pg. 371). This descriptive interview approach allowed for construction or reconstruction of knowledge to produce meanings and understandings of the phenomenon (Mason, 2002). Additionally, this format for qualitative interviews allowed for the knowledge, understandings, interpretation, and experiences (Mason, 2002) of the 4-H Agent to be explored through rich, thick description (Geertz, 1973).

Analysis Procedures

In order to make sense of the data, analysis occurred through the interrogation and organization of data for the production, synthesis, and evaluations of patterns, along with identification of themes and relationships (Hatch, 2002). Interviews were first be open-coded (Strauss and Corbin, 1990) by assigning descriptive labels for the production of significant characteristics (Bailey, 2018), with line-by-line coding utilized when possible. An iterative, inductive process was then be used "to form increasingly more abstract units of information" (Creswell, 2013, pg. 186) for comprehensive themes production. As multiple interviews were coded, each set of codes were likened through a constant comparative method (Glaser and Strauss, 1967) to check for accuracy and to produce qualitative validity (Creswell, 2013). This assessment of similarities and differences "allows the researcher to differentiate one category/theme from another and to identify properties and dimensions specific to that category/theme" (Corbin and Strauss, 2008, pg. 73) while systematically producing themes that are "consistent, plausible, and close to the data" (Glaser and Strauss, 1967, pg. 103) without utilizing provisional testing of hypotheses (Glaser and Strauss, 1967).

Chapter 4: Results and Data Analysis

Research analysis revealed trends, gaps, and emergent themes surrounding STEM and engineering education within 4-H programming. Findings were analyzed to produce eight themes emerging from the data. These findings are listed with their connections to research questions or content areas.

Research Question 1: How do 4-H educators see engineering integrated within the 4-H STEM curriculum, projects, or programming?

Theme 1: 4-H agents articulate STEM, including engineering, as separate content areas – often only identifying science content

STEM is not seen as integrated, but separate content under one STEM umbrella

4-H agents often defined STEM as the separate content areas of science, technology, engineering, and math. They were able to give example curriculums or programming that belonged in each content area separately, but provided no indication that STEM was interpreted as an integrated concept. Rhonda stated that:

> STEM education is anything related to science - Natural resources, animal sciences kind of things. Technology, like in computer programming those kind of topics. Engineering - the building, the physics, that type of stuff. And then math is kind of encompassed in all of those things.

This lack of integration continued throughout statements by participants, suggesting that engineering is not seen as integrated into 4-H STEM, but rather that engineering is articulated as its own content area.

Furthermore, agents articulated STEM curriculum utilization as completion of only one content area. For Nicole, when she teaches science topics such as natural resources or agriculture in her in-school or out-of-school programming, she considers herself teaching STEM, regardless of whether or not this activity includes any direct or indirect correlations to technology, engineering, or math. This data suggest that while engineering might be considered a content area of STEM, there is disconnect between how content areas can and should interact within STEM programming.

STEM is heavily understood as a science first activity, specifically through scientific method.

When asked what STEM programming within 4-H specifically looked like, agents gave examples dominated with scientific understandings, suggesting that STEM and science are understood as synonymous. Programs ranged from science fair, cooking, and gardening examples, and were often described through the scientific method. Agents utilized terms and phrases commonly associated with the scientific method such as hypothesis formation, methodologies and data collection including measuring and weighing, record keeping, data analysis, and statistics representation through averages and data charts. Additionally, agents often articulated the importance of understanding the scientific method as a way to defend what was discovered, clarify understanding, and work in a team.

Agents also recognized both the need and connections for 4-H programming that aligns with Virginia Standards of Learning (SOLs). When asked whether Ava finds herself following any SOLs in her out-of-school programming, she responded:

> Yes specifically scientific investigation. That, the administration has said that's one that kids particularly struggle with and it's one that doesn't go away. That's the basis of all their science classes. And we do a lot of scientific investigations. And really, I mean STEM in the garden. And even with our foods programs, we really get into the science behind food preservation; we do our canning workshops and that sort of thing.

Strong background knowledge in formal and non-formal science educations suggest an additional reason for heavy utilization of science content and understandings in 4-H STEM programming. Many agents reported bachelors and masters degrees in a variety of disciplines including environmental issues, forestry and wildlife, microbiology, and general science. Additional certifications through entities such as Virginia Tech and the Chesapeake Bay Foundation added to the certifications affecting the understanding of science content. When asked whether these backgrounds were a part of STEM, agents heavily replied yes, again indicating that STEM and science are synonymous, and that STEM can be characterized as a science focused entity without requiring an understanding of technology, engineering, or math components.

This level of knowledge surrounding science resulted in two common categories regarding science programming: increased comfort level and increased 4-H education. When asked about their comfort in teaching STEM curriculum, agents indicated they were very comfortable, though many specifically indicated this was only with science content. Erika specifically stated:

> I do feel comfortable with [STEM programming]. I'm more knowledgeable and more often focus on the sciences. I don't, and I know your study is on engineering; I don't rely on engineering as much I'm not quite as comfortable with that.

This passage indicates that there is a connection between the level of knowledge on a specific topic and the level of perceived integration of this content into STEM and 4-H programming. In other instances, agents indicated that the idea that a lack of knowledge, particularly around engineering applications, resulted in a lack of integration of engineering content and discussion into 4-H programming. This lack of confidence in engineering will be expanded on outside of the research questions.

To further elaborate on 4-H STEM programming, Erika stated, “Anyway, my background is in environmental science which is probably one of the reasons why I focus so heavily on [STEM].” Erika expanded upon this level of focus. When asked about her level of involvement with STEM programing in 4-H, she stated: “I actually do a lot of my programming with STEM. And mainly because I have a really strong environmental science and Watershed education program targeting our middle schoolers, but we actually do a unit in the 2nd grade as well with that”, therefore suggesting that a strong educational background in science can lead to a focus on and successful implementation of STEM topics.

Theme 2: Engineering characteristics exist within programming, but are absently or incorrectly labeled as engineering

When asked to specifically identify engineering connections or characteristics, agents often struggled to verbalize terms or phrases utilizing engineering understanding. In some cases, engineering was used and identified by the agent, but those engineering connections were not articulated to students at the beginning or throughout the activity. The key importance of this finding connects to research on the Nature of Science, as well as recent understandings of the Nature of Engineering. These efforts indicate that science and engineering need to be explicitly understood and articulated by educators (Clough 2006; Pleasants & Olson, 2019), or else students do not realize they are engaging in authentic practice, which leads to the generalization to science of engineering as a field.

In one instance, an agent identified an engineering activity during the interview regarding vertical gardening and design of a trellis system. However, this activity was communicated to the students as a team building activity, but not as an engineering activity. Design challenges were also often communicated this way, as many agents found themselves focusing on how students worked in teams instead of on the engineering design process. At other times, agents found quick design challenges that followed multiple steps of the design process as “time-wasters” and did not articulate these activities through engineering terms, even though they were identified as such in this interview process.

In other cases, agents would describe common engineering characteristics, but would never verbalize their understanding of these activities as engineering. During one of her activities, Ava stated:

> Yeah when they're launching their rockets you know and they have to figure out how hard to step on the bottle, you know, are they gonna over shoot or under shoot? And does it go off to the right or off to the left? Or you know what if we added fins? What do you think would happen? And so we’ll add fins, we’ll try it that way - we’ll adjust the angle, that stuff. So they get to try different things and you know tell me what worked and what didn’t.

In this instance, Ava described many components of engineering design including identifying variables around a problem, selecting possible solutions, building a prototype, testing and evaluating that prototype, redesigning, and communicating the results. Other agents articulated similar cases, many of which focused on the trying and retrying involved in design as a process. However, these steps were not communicated to the students through engineering connections, therefore suggesting that there is not a lack of engineering integrated into 4-H programming, but rather there is a lack of known engineering terminology and phrasing.

For agents who more easily described the design process, they indicated that engineering had been integrated into STEM Day Camps or school programs through catapult of tower building, but that those were not entirely engineering focused. For example, Erika described that for an activity to be engineering, she would "need to find a curriculum that would kind of take, I would say, take a group through some very basic engineering design and up through something more complex over the process." This description of engineering suggests that engineering is not seen as a content area that can be integrated into curriculum and rather exists as its own independent entity.

Additional barriers appeared as reasons for a lack of engineering identification within 4-H STEM programming. For example, many agents focus on students in elementary and middle school and have found that these students do not directly ask for engineering driven curriculum. As such, agents with limited knowledge and confidence in engineering are the only catalyst likely to increase engineering programming, meaning engineering is not heavily discussed. Moreover, agents identified that design – even when not described through engineering characteristics – required a higher level of flexibility and independent learning from the students. When students would become distracted or stuck during the design, it was difficult for the agent not to redirect them or give them a specific answer, though some agents indicated they have grown more comfortable with ill-defined design curriculum over time and with increased frequency. During some of these flexible design instances, specific answers did not exist, as is the nature of the design process. In others, answers could be given, but they would defeat the learner driven process.

Research Question 2: What characteristics of engineering are emphasized as important in the teaching of engineering within the 4-H curriculum, projects, or programming, and why are these characteristics important?

Theme 3: Engineering characteristics include a variety of complexities and terminologies

The most dominant characteristic associated with the concept of engineering was design and the design process. When asked to describe how engineering was characterized, Stephanie stated "giv[ing] them an opportunity to work through that engineering design process where they would identify a problem and then come up with a solution. You know try that solution out and then go back to the drawing board and tweak it and try it again." She continued in her description of the design process by stating that:

> … then we talk about, well you know this robot kind of failed in its, its job as well. So now the task is to figure out how to make it more effective. And then they would have an opportunity to go back and make changes and run it again and then, you know, after they had their results we would do the same thing. You know what was your percentage? Hopefully the percentage went up. But we'd just give them several opportunities to see how high they could get, that they could get that percentage.

Many agents echoed similar details, particularly around the idea of designing, redesigning, and the evaluation of what went wrong and what went well. "Troubleshooting" and "prototype" were often used to describe the design process, particularly during the redesign phase. During engineering activities, students were also encouraged to report their findings to the wider group and often completed their designs in a group setting.

Of the agents who described engineering using design terms, their understanding of the process was cyclical, though very few utilized that term directly. Agents also communicated their lack of using these terms throughout the activity, stating more often that they might describe the process at the beginning of the project, but not as the students are moving through the process. Erika, however, did deliberately integrate engineering terms throughout the process. She also articulated an advanced understanding of engineering terms and applications as compared to most other agents in this study.

Within the design process, agents mentioned specific concepts repeatedly. One of these was problem definition. Connections were made by the agents concerning the importance of the problem and its relationship to solving that need, and being able to utilize only certain materials to solve the problem. Christina expanded upon this idea further by stating that "as they go through the process, they determine, you know, is it possible or is it not possible or… What am I going to need to be successful in this, this project?" Another agent communicated these requirements for success as "research" and stated how she encouraged students to look for solutions that already exist that might help with the design around this specific problem.

Some agents also discussed constraints, criteria and variables within the design process. While most agents did not use the terms "constraints" or "criteria", they stated that they would limit the materials and give students requirements for their designs, as well as establish clear goals that defined what the design was required to accomplish. One agent, Madison, even went as far as to integrate monetary values into her project, therefore requiring students to determine which items they would use within a set budget. Madison described this interaction by adding that:

> What I think works best is if you have a kit of materials, like if you got, everybody's got the same number of popsicle sticks or paper brands or what, you know everyone's got the same group of equipment. Or a way you know the same ability, access to it. I know one

of the, one of the things I did with junk drawer robotics, they had money, paper money and they had to purchase their, their pieces and so they were trying to make it as efficient as possible as well as make it work.

This data suggest that agents are not only considering physical limitations on materials, but additional complexities are being integrated, though it is unclear if this is considered to be an engineering characteristic.

For some agents, design was mentioned as a characteristic of engineering, but when giving examples of engineering curriculum or projects, design was absent. In one instance, Christina described her experience with engineering curriculum as follows:

Researcher: Could you tell me more on how you see that [project] fitting your engineering characteristics?

Christina: Well because they have to test the strength of the magnet and its abilities to go through different kinds of objects.

Researcher: Is there any design component involved in that project?

Christina: Just really designing their maze and that's about it.

During this activity, Christina described how students designed a maze through which they had to navigate their magnetic prototype. However, design was not discussed with this prototype, though testing was articulated as a component of that program. In this case, where the agent titled the project as an engineering activity, terminology associated with engineering design was sparse, but the ideas surrounding the process remained. Other agents described similar situations where their engineering examples did not utilize design terminology, but did follow design processes.

One final group of agents limited engineering characteristics to those embedded in building. For these agents, any type of building appeared to be classified as engineering including Lego's, towers, and Keva Planks. In this group, however, design components were not described within the idea of building. Instead, the simple characteristic of building qualified a program as an engineering curriculum.

Theme 4: Agents relate engineering understanding to personal relations and Do Reflect Apply model

In order for agents to have formed their understandings of engineering characteristics, they must have interacted with the concept of engineering in a previous way. For many agents, exposure to engineering has come in the form of family relationships, including nephews, brothers, and husbands. In one instance, Christina described her nephew, a mechanical engineer as a child who "always tinkered with stuff and you know, was one of those kids that would tear part toys and put them back together." Another agent described how her brother often observes physical structures such as houses and questions why choices were made in the design of these buildings. In all instances, the ways in which the agent described the engineering through whom they interacted was reflective in the terms utilized in the characterization of engineering. It is worth noting that all personal relations mentioned in this data were with male engineers.

Data suggest that many agents have and can form an understanding of engineering through the Do Reflect Apply model often used as a base for experiential learning within 4-H. For some agents, these steps were internal to the programming, where the students would "Do" the design, would "Reflect" on what occurred and resulted from the design, and "Apply" a different technique of what they need to improve for the next round of changes. Erika expanded upon the importance of the "Reflect" phase, indicating that:

> The kids don't always recognize that they've made a prototype or that they've done troubleshooting, so sometimes it's in that reflection phase that I'll bring up the term and describe the term and ask if that's something that they did or how they can tell me about doing something in that. And then it's kind of like a light bulb goes off that "hey, we did that" and they explain, you know what they did that fits with that term. Because lots of times, of course it depends on the age, but they really don't put two and two together with the term and what they did.

This data suggest that it is important for agents to directly connect STEM and engineering concepts to the model in order for learning to occur, but that the exact phase in which application occurs is likely of less importance and can rather be guided by student interactions.

For some agents who strive to make applications to broader understandings external to the immediate lesson, the application phase is articulated as important but challenging. Nicole, for example, notes that, "I think the do and reflect I can totally handle pretty much anything. It's the applying with engineering, it to me kind of gets above my head you know", suggesting that when asked to define engineering as more than the immediate task with a few redesign components, the importance of engineering characteristics is lost. Further data continued to support this idea that agents are able to define an engineering curriculum in the "Do" phase, potentially characterize the importance of "Reflect" through the redesign, but few were able to "Apply" engineering concepts outside of this pre-established understanding. For examples, when asked to elaborate on why an identified project was considered engineering, they would simply restate the project, indicating that the characteristics around Keva Planks or Lego's Robotics is engineering, but further application was challenging.

Theme 5: Agents identify important STEM characteristics and concepts, particularly with lesson planning considerations

While the data suggest a limited ability to readily identify the importance of engineering characteristics and concepts, agents were able to connect STEM components to a variety of important skills and motivations. For example, many agents discussed STEM using community and local connections, particularly those related to environmental science settings. While interacting with watershed education or touring a local pond, agents would ask what students could do to positively affect their own watershed or pond. Erika expanded on this concept by stating "we look at specific practices that [students] can do based on what they've learned or that they could investigate further to find out more", suggesting that agents understand the importance of student knowledge being applied to personal connections.

Another set of agents emphasized the importance of student motivated discovery and how STEM curriculum must be manipulated to fit the interests of all students. For example, Sarah discussed how one of her STEM projects, building an animal home, was not of interest to certain students as they did not care about rabbits or squirrels. To engage those students fully, Sarah asked the students what animal they would care to design for, thus allowing the student to engage with an application that made a connection to their interests. Rhonda articulated this further in a more general outline, stating that "with natural resources, as [students] experience something, as they discover something, then we start talking about the concept and move out from there. Because it was kind of a self-discover and then we relate the concepts to whatever it is that we're dealing with," once again reiterating the importance of individualized learning within group curriculums.

Data also suggested the requirement for STEM lesson plans to be flexible, particularly due to age and time constraints. While this detail may also be necessary for non-STEM curriculum and projects, agents specifically self-identified lesson plan flexibility as being important to STEM. For multiple agents, it is apparent that elementary aged students to not want to plan, draw, or sketch the design, and instead want to jump directly into the hands-on phases. Agents further recognized that while this does not follow the design process exactly, it is likely the only facilitation method that will keep the student engaged, noting that lectures of more than a few minutes result in disengaged students. Ava went as far as to state that "a lot of times what I'll do is not give them a design or not give them a plan, just give them the materials and say you know "how would you make this work?" and let them try to figure it out on their own", once again supporting the claim that STEM curriculum, including those connected to engineering, must remain flexible in a variety of ways. This concept of emphasizing experience before explanation is also a key connection to experiential learning as modeled through the Do Reflect Apply 4-H model previously mentioned in Theme 4.

Another level of flexibility inherent to STEM programming with 4-H is the time constraints. For example, Colleen articulated that her groups often meet for only one-hour timeframes, which require her to skip some of the steps in either the engineering design or scientific method. As a result, this skipping meant that "maybe [we're] not giving full attention to building a second prototype for example. So we get some things that don't work but they seem to learn from the failures as much as they do from, from making something that does work."

Research Question 3: How did these 4-H educators, through formal or informal training, influence, student interest, or other, come to utilize these characteristics to describe or discuss engineering?

Theme 6: Volunteers and teachers play an important part in 4-H STEM formal and non-formal learning efforts

While many agents indicated they are comfortable in certain components of STEM education, they also acknowledged that their strengths do not always align with the needs of the students. In some instances, agents simply do not have the background experience or interest with a certain curriculum and do not have the time to expand their knowledge. Engineering curriculums, particularly robotics, were often examples of programs that would not exist if the agent were required to spearhead the initiative. As a solution imbedded into the 4-H organizational model, many agents have engaged with volunteers to lead their STEM clubs, challenges, and speak about career connections at STEM camps. Volunteers also offer a stepping-stone when agents were hesitant to initially engage with STEM related activities, potentially allowing the agent to become more familiar and comfortable with the content.

Since many volunteers are equipped with a background in education, 4-H, or interest in STEM, they are interested in "draw[ing] some connections to STEM when they're doing their activities." Erika elaborated that "when [the volunteer is] weighing the animals, when they're designing something to make the animals stand up on their hind legs to build more muscle or different things like that she'll draw some [STEM] connections." In this case, it is more important for the volunteer to be able to articulate STEM connections and characteristics than the agents themselves. This is further supported by data surrounding STEM non-formal programming for Sarah, which:

> … are almost entirely volunteer run, so in many cases I'm not there. And so it's a matter of what can I do to make sure that those volunteers will be successful, have a good program with those kids. Enjoy the process… So I think we don't do as good of a job

> communicating those [STEM] links as we need to, it's more that's it's implicit, that it's implied in the process.

While this data suggest that the agents could still have an influence on STEM connections by training their volunteers – an effort other agents indicated they engage with – many agents are less focused on the lesson planning and curriculum development and more on the logistics of running a youth development program. This finding aligned with personal communications with 4-H administration who indicated that agents focusing on the logistics are typical in some county settings.

One subtheme that emerged with regards to STEM volunteers are the limitations and improvements surrounding these participants. For example, many volunteers are inherited from previous county agents, are associated with professional certifications such as Master Gardener or Master Naturalist, or were previous 4-H members themselves. Generally, agents did not indicate that they seek out STEM volunteers, but were thankful when they do assist with programming. Additionally, when volunteers do emerge for STEM programming, limitations such as money and time keep them from improving their education or STEM development. Erika, whose volunteers were noted for making STEM connections during their programming, attends professional development and training sessions. For the volunteers that do not attend such trainings, they were not noted as being able to verbalize STEM connections or terminology within their STEM programming.

This lack of trained STEM volunteers was noted as detrimental to the communities, as the agents realize there is a significant interest in STEM, but programming is limited to someone with a comfort level in teaching STEM curriculum. As STEM programming grows more specific, this concept becomes increasingly important. Georgia, with regards to engineering programming, stated that "I'm comfortable facilitating simple activities, but when it becomes something where I need to teach a specific concept, I would defer to a volunteer or a guest speaker or something like that," suggesting that if a volunteer were not available, that content would go absent.

During formal, class-based learning, teachers are often the motivation for STEM activities within the classroom. In some instances, teachers are learning about STEM programs that 4-H facilitates such as Makey Makey and Rockets to the Rescue, and utilizing those programs to expand connections between the arts and STEM or to improve their classroom hands-on experiences. This connection with teachers also often involved interactions with grade appropriate SOLs, specifically when the teacher might need help facilitating those topics. Ava further expanded upon this by stating the partnership "also helped us to write some grants, we wrote a grant to get some ocean current models because the teacher said that they were struggling with that particular part of the test - waves, tides, and current. The ocean current models really help them visualize that."

Theme 7: While "non-obvious" STEM curriculums exist, agents do not personally manipulate engineering programs

One significant data theme articulated outside of the established research questions is how STEM curriculum can exist in non-obvious applications such as sewing, cooking, and art. However, data suggest that agents do not often engage with non-obvious applications for engineering programming. When asked to give examples of engineering projects or curriculum, agents mentioned a variety of robotics and rocketry applications including Junk Drawer Robotics, First Lego League, VEX Robotics Competition, and Rockets to the Rescue. Other recognized projects were Power of the Wind and Keva Planks, particularly for agents who defined engineering in terms of building. Unlike with general STEM programming, however, when agents were pressed to apply what they understood about engineering to curriculums, only the above stated standard answers were given. This ability to apply general STEM understanding to programs outside of "traditional" STEM context, but lack of ability to do the same for engineering specific context, suggests agents do not take the characteristics they understand about engineering and apply them to their own programming.

Data suggest that even with the difficulties surrounding current engineering understandings and applications, agents have been motivated and willing to expand their utilization of STEM programming. For many agents, this involves locating state curriculums that incorporate STEM and engineering components, as well as searching the internet for potential activities or lesson plans. Additionally, agents indicate that after attending professional development trainings, they have gained confidence in their STEM abilities, providing promise that engineering specific integration can also improve within 4-H.

Theme 8: Barriers to engineering understanding including severe discomfort and low confidence

While not within the confines of the indicated research questions for this study, an unexpected theme of discomfort and low confidence within engineering understandings appeared within the data collected. Multiple subcategories influenced this discomfort and low confidence including professional development and 4-H structural barriers.

Professional development barriers

While STEM and engineering understanding play an important role in education, pedagogical understandings are also important with regards to successful learning. For many agents, the short structure of 4-H workshops, ranging from one to two hours, limit their ability to both understand engineering as well as learn how to best teach those topics. Nicole indicated that at these trainings, the focus is “usually the whole build this, build that, they give you a whole bunch of materials and you make something kind of thing. That's pretty much it really.” This data suggest that while tools are provided for engineering teaching, practices around effective implementation are not the focus of current trainings in 4-H. Nicole further elaborated on these engineering trainings stating “that did have some engineering but as far as like breaking it down as to what the pieces were or anything, it was more, it really didn’t go that way.” While this type of professional development provides agents with materials, it does not appear to build upon the inherent understanding of engineering connections or concepts.

4-H Structural barriers

Unlike other youth development programs, 4-H agents in this study were not primarily involved in the direct education of students. As briefly indicated previously, data suggest agents spend much more of their time assisting volunteer educators with logistical or funding needs, or in some instances, train those who might directly deliver STEM content. Erika indicated that she is a facilitator for Project Wet, Project Wild, Project Learning Tree, and Project Underground, “so not only do I deliver these programs to kids but I teach others. And train others in using the curriculum.” For other agents, they interact even less frequently with students directly and instead are a resource for curriculum and projects that others can implement. As volunteerism increases for 4-H, it will be increasingly important that agents are able to teach volunteers how to lead STEM educational programming as opposed to the need for agents to be able to complete this task themselves.

These barriers, along with the data collected that suggest very few if any 4-H agents have a formal background in engineering or engineering education, which can lead to low confidence and comfort in engineering facilitations. Since STEM and engineering are not often the major focus of curriculum within 4-H, agents are only infrequently exposed to STEM content, therefore lowering their comfort level. Additionally, many students are more heavily involved and at times are more knowledgeable about STEM content, creating discomfort around many traditional educational approaches.

Lastly, data collected during this study suggest that engineering is assumed to require high level of creativity and often does not include one correct answer, therefore leading to a lack of confidence and comfort for some agents. When coupled with the idea that engineering is a daunting discipline, requires an advanced level of education, and higher, more complex analysis, data often suggest that 4-H agents panic and are nervous when asked to engage with engineering programming. This lack of confidence is leading to further disengagement from agents.

Chapter 5: Discussion, Conclusions, and Recommendations

Discussion

Specialized Content Knowledge

Data collected within this study align with the many components of the theoretical framework and literature within STEM and engineering understandings and education. Throughout this research initiative, data supported the importance of Specialized Content Knowledge (SCK), or the procedural and conceptual understanding necessary for teaching and recognition of student errors (Ball et. al, 2008; Ball et. al, 2009), suggesting that when this understanding does not exist, educators are less confident and less likely to initiate engineering within their STEM programming. Data also indicated a lack of skill and understanding to analyze student interactions, provide clarification, and utilize suitable imagery for concept representation, details also important to SCK (Hill, Rowan, & Ball, 2005). This finding suggests that even when engineering occurs within 4-H STEM programming, agents are unable to identify these engineering connections and are unable to further assist students in the learning process surrounding engineering.

When SCK is broken down further into three components, representation, justification, and explanation (Lin, Chin, & Chiu, 2011), researchers can begin to analyze where exactly engineering knowledge is lacking. For many agents, this first level of SCK was inconsistently utilized, as some agents were not able to represent engineering effectively within their programming. Oftentimes these agents would not vocalize engineering terms or concepts when their students engaged with these ideas successfully. Additionally, these agents did not outline engineering activities within an engineering framework, therefore allowing for design, testing, redesign, and even evaluation without acknowledgment of a link to engineering concepts.

According to Ipek (2018), representation can expand to external representations including real-world contexts, models, or expressions of engineering. Many agents directly indicated their inability to apply engineering content to real-world examples, often resulting in connections from the engineering program to life skills – more often referred to as 21st Century Skills or "soft skills" in non-4-H contexts. While these connections are valid and of great importance to 4-H curriculum, they do not suggest that agents are able to represent engineering understanding outside of the immediate lesson. This group of agents, therefore, failed to meet the first SCK standard – representation.

A second group of agents unsuccessfully navigated the second level of SCK, as these agents were unable to justify and describe engineering considerations and ideas. For example, some agents struggled to articulate components of the engineering design even though they identified design as an important part of engineering. Often agents would acknowledge the need for materials and testing, but would not outline the need for criteria, constraints, and formal evaluation of the prototype. This was also seen with the idea of building. While agents recognized that building could be a component of engineering, they were unable to describe the process of building within engineering ideas.

Furthermore, this lead to a lack of meaningful, higher-level learning for the students, as they were not required to express deep understanding or justification for their actions. For example, while agents identified that students were encouraged to try their designs again after failure, there was no indication that students were required to think through why their design failed or what components of their design might specifically lead to more successful results. This missed connection is a result of the simplified understanding of the Process and Generalization steps within experiential learning, as 4-H combines these concepts within the "Reflect" stage.

Within the traditional experiential learning model, the process of building new knowledge is more strongly emphasized, and appears to be lacking in 4-H STEM programming. Without necessitating this level of higher thinking, students are allowed to retry, but are not doing so within any predetermined constraints of the design needs. This lack of justification of engineering considerations and ideas, both with the agent and materializing with the student, suggests that this second group of agents failed to meet the second SCK standard – justification.

For other agents, they were successful in representing engineering, as well as justifying engineering ideas, but when asked to physically manifest these understandings into curriculum, their answers fell short. For example, while many agents listed 4-H curriculum such as rockets or robotics as engineering focused, they were unable to explain the process and procedures within this curriculum through common engineering practices. In many cases, agents were unable to articulate the importance or need of engineering design in these experiences, and instead simply associated these tasks with the need for design. Data from this study also suggest few if any agents made a connection to a problem statement or need within these engineering curriculums, potentially hindering their ability to further explain the process through common engineering practices. Overall, this grouping suggests that some agents are able to identify engineering, potentially describe engineering considerations, but unable to articulate these items fully within an experiential learning activity, therefore failing to meet the third SCK standard – explanation.

It is important to note that some agents were in fact able to meet all three levels of SCK as they were able to articulate examples of effective engineering representation, describe a robust narrative of engineering considerations, and offer explanation for common engineering practices within engineering practices. However, data suggest that few, if any, agents are able to reapply their understanding of engineering to individually developed curriculum. In cases of curriculum not immediately identified as engineering, such as watershed education or dog training, agents were unable to fully describe how these examples met the engineering practices. Oftentimes, this resulted in the agents stepping back and questioning if their example really was engineering, but never being able to explain exactly why they now questioned their assessment. This shift in understanding suggests that while agents are beginning to understand engineering, they do not yet have the ability to successfully apply and recognize engineering connections outside of standardized, predetermined engineering curriculum.

Self-Efficacy

During this study, themes surrounding self-confidence and comfort level with engineering curriculum emerged. The concept of self-efficacy is “belief in one’s capabilities to organize and execute the sources of action necessary to manage prospective situations” (Bandura, 1986). While self-efficacy occurs in a variety of situations, it is specifically important during activities that require successful navigation of a perceived barrier, such as engineering curriculum and applications for educators without an engineering background. Additionally, self-efficacy affects whether a person decides to take part in an endeavor, how much effort is put into that action, whether the person’s thoughts aid or hinder the self, stress or discomfort experienced during these activities, and whether the action is seen as accomplished (Bandura, 1997). Ultimately, self-efficacy plays a role in determining whether or not an activity is conducted again.

It should be noted that confidence is only a component of self-efficacy, as confidence does not require that the outcome of the interaction is positive. For example, a person can be confident and still partake in an activity that was seen as a failure (Bandura, 1997). In this study, this is particularly important as some agents identified themselves as being confident in STEM education, but were unable to accurately utilize STEM curriculum. In these cases when the outcome of the STEM activity is not accurately accomplished, self-efficacy has hindered the correct execution of the action. Broadly speaking, someone can be confident in an action but still be doing that action incorrectly. As engineering confidence increases, similar instances where understanding and execution are not equal may also occur, suggesting the need for validation of agent claims through expert observations or other research efforts.

For agents involved in this study, multiple scenarios involving self-efficacy occurred. For example, some agent indicated that they do not initiate engineering curriculum as they are not "wired" that way, or do not fit their preconceived narrative of an engineer. Even when agents indicated that STEM and engineering curriculum appear to be well-received, and at times even in high demand, throughout their community, agents were unable to overcome the barrier caused by low self-efficacy. For agents who were able to become involved in engineering curriculum, whether directly or through a volunteer/teacher, self-hindering thoughts of low comfort, potential anxiety or stress, and low knowledge kept the agent from improving their view on their ability to successfully implement engineering programming.

In one instance, the agent refused to discuss engineering applications on face value as she insisted she did not engage with engineering programming. This ran in contrast to her engineering understanding, however, as she was able to very effectively articulate engineering components and connections that were used in her own programming. In this case, the self-hindering thoughts of inadequacy and perceived low knowledge kept the agent from even acknowledging engineering, and instead insisting that her volunteers were the only 4-H educators successfully utilizing engineering curriculum.

It was unclear if agents experienced discomfort or stress during the implementation of engineering programming, or whether their discomfort and stress materialized due to the previously mentioned examples of low self-efficacy. It is also unclear if agents felt their engineering programming was successful, both with regards to student learning and curriculum implementation. Further research is suggested to follow-up on these distinctions, as it is important to understand the full breadth of self-efficacy related actions surrounding engineering before implementing professional development.

Pedagogical Content Knowledge

While not within the scope of this study, further discussion of Pedagogical Content Knowledge (PCK) is needed, particularly with regards to its applications within experiential learning. Many agents indicated that while they do at times directly facilitate STEM and engineering curriculum, volunteers and teachers are more often those leading the educational initiatives for 4-H learners. Data from this study suggest that while Specialized Content Knowledge is still needed, and that Baumert et al. (2010) acknowledge PCK is unobtainable without some level of SCK, volunteers and teacher may already have the SCK necessary to successfully understanding engineering, or at a minimum, an ability to overcome the self-efficacy barriers seen with many agents.

Pedagogical Content Knowledge (PCK) focuses on the educator's ability to foster understanding of a concept or subject for the learner (Shulman, 1987). Additionally, PCK "also includes understanding of what makes the learning of specific topics easy or difficult; the conceptions and preconceptions that students of different ages and background bring with them to learning" (Shulman, 1987, p. 9). As indicated from the data of this study, some agents appeared hesitant to include engineering in curriculum for elementary students, which aligns with results from the Leonard Gelfand Center for Service Learning and Outreach at Carnegie Mellon (2008) which found that educators questioned whether engineering could be taught to younger students. In examples such as this, the Specialized Content Knowledge surrounding engineering is important, but potentially less important than the educator's abilities to recognize how young students might understand and engage with engineering appropriately.

When tied together with experiential learning, professional development surrounding PCK can be approached in a way that 4-H agents are already familiar. This is specifically important for engineering applications as the way one thinks about the experiential learning cycle is influenced by the goals and learning objectives of the program or project. While it appears that the cycle can be aligned with both engineering and 4-H learning outcomes at the same time, it is not articulated in that way. For example, 4-H goals and learning objectives are heavily focused on team building and leadership, and often less on specific content. Therefore, when agents move through the experiential learning cycle and engage in processing and generalization, they often will focus primarily on the goals of 4-H instead of content of STEM or engineering alone. For future professional development, particularly with regards to PCK, practices that acknowledge and utilize both the knowledge of 4-H goals and the knowledge of engineering/STEM content simultaneously within the process and generalize portions of the model will likely be most successful.

Conclusions and Recommendations

This study is the first known to specifically target engineering understandings and utilizations within 4-H STEM programming. Within the commonwealth of Virginia, multiple trends seen on the national level or in other states were confirmed. For example, many 4-H agents defined STEM education with a science first mind frame (Bybee, 2010), where some agents required other components of STEM to also be included while others defined science only curriculum as part of the STEM umbrella. Also indicated in previous research (Bybee, 2010), this study suggests that until STEM education, through model units, professional development, or assessment, intentionally integrate interdisciplinary STEM understandings, curriculum will continue to be viewed in this way. This finding is important for all future engineering education initiatives, as engineering is not only seen as the missing link that joins math and science skills and knowledge with technical and societal innovation, (NCTL, 2015, "The Missing Piece"), but is not a content area most 4-H educators or young students are directly knowledge on.

This study did thematically result in the recognition of non-obvious STEM applications for learning, suggesting that previous professional development efforts aimed at recognizing "STEM Hiding in Plain Sight" are being understood and implemented. This result provides a positive outlook for engineering implementation as agents are successfully utilizing the professional development efforts geared towards STEM integration. As this understanding improves and agents are more readily able to identify new ways through which STEM can be articulated in programming, there is promise that engineering can be improved along those same lines. This effort is supported more heavily by the finding that many agents are utilizing engineering concepts and connections, but that specific improvements such as application and term recognition are needed to increase engineering programming. In many ways, this limitation mirrors what other researchers claim was observed in 4-H programming.

Specific professional development adjustments should be made to more effectively understand prior engineering knowledge of 4-H agents. For example, the finding that agents showcase a broad range of engineering characteristic complexities suggests that trainers may need to be more aware and respond more directly to the variety of understandings within one room – a concept that ties to adult education and adult program planning theory. In this way, it is important to separate where agents are with regards to the SCK – whether they are struggling with representation, justification, or explanation – as each calls for a slightly different approach to professional development. It is equally important for trainers to understand the engineering self-efficacy of educators and be able to determine when SCK outweighs PCK in professional development importance.

For example, those responsible for continued professional education of extension educators should consider how much engineering content is necessary for 4-H educators to articulate the goals and connections desired by their work. In some cases, agents may need to improve their engineering content knowledge if they are heavily involved in direct student programming. For many agents, however, volunteers lead these types of activities, suggesting that professional development should instead focus on how to make engineering connections to 4-H goals such as improved career readiness, life skills, team building, and leadership, as these are concepts agents are actively teaching to their volunteers. By focusing professional development on the goals of 4-H, STEM initiatives can more readily align with the content and contexts that are the primarily learning objectives for these programs and project.

Another avenue through which to improve engineering connections and applications could be the concept of failure. This idea was heavily expanded upon throughout this research project and appeared to contain a positive level of comfort for the agents. Many agents articulated their comfort with asking students open-ended questions that could steer them towards an answer. Most agents identified their ability to successfully navigate student failure in design, even in instances where they were not communicating engineering connections. In a study from Gibson and Dembo (1984), high-efficacy teachers spent more time than low-efficacy educators utilizing questions to guide students towards possible answers, suggesting that while 4-H educators might not have high-efficacy specifically within engineering, they utilize strategies of high-efficacy educators. This result suggests that future trainings that connect redesigns, necessitated by initial failures in design, could be a prime opportunity to engineering discussions and understandings.

Lastly, agents were continually able to articulate their use of the Do, Reflect, Apply model, as well as its connections to activities within 4-H. Even when presented with barriers including materials or time, agents commonly referred back to this model and how their learning experiences attempted to integrate this process, knowing this approach would successfully move the learning forward. These findings are of utmost importance to future studies and ultimately tie together multiple considerations within previous research efforts.

Do Reflect Apply offers a platform through which to discuss engineering without introducing characteristics that might otherwise deter engineering professional identity development. For example, many educators are discouraged from engaging with engineering curriculum as they themselves do not identify as engineers. By introducing engineering in a way that can be connected to previous experiences of 4-H agents, their initial distaste – potentially supported through years of low self-efficacy around engineering – can be decreased and allow for learning within engineering to occur. Therefore, recommendations for professional development could capitalize on this Do Reflect Apply approach and focus on ways to connect engineering design to this same model.

Ultimately, STEM and engineering education have a place within both formal and non-formal 4-H programming. These educational initiatives, ripe for improvement regarding understanding and implementation, play a key role in the ability of youth to expand their interest of the world alongside their capability to solve wicked, global problems. STEM and engineering education offer the interdisciplinary thinking necessary for the development of critical thinkers, an effort aligning with the national efforts of the 4-H Development Program.

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