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Intentional STEM Infusion (ISI) Approach for 4-H Non-STEM Project Volunteers: Finding STEM in Plain Sight

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STEM literacy is identified as a necessary skill for participation in the future workforce. 4-H has responded to this need to develop STEM-ready youth by expanding access to project areas like Robotics. It has been acknowledged that recruiting and training STEM competent staff and volunteers is a limitation in expanding these types of programs. At the same time, 4-H youth are enrolled in many traditional non-STEM projects that are imbued with STEM concepts. 4-H volunteers with increased awareness of their role in fostering STEM education and STEM literacy can be a valuable resource in preparing 4-H youth with STEM-ready professional skills. 4-H professionals can train front-line volunteers to use an intentional STEM infusion approach within the experiential learning process. It is posited that volunteers will be better able to facilitate STEM learning in real-world contexts for a wide-range of 4-H youth by using this approach. The use of the ISI approach provides an opportunity for 4-H to develop more STEM-ready youth than by only serving those youths who are attracted to STEM-focused projects alone.

Keywords: STEM literacy; integrative STEM; 4-H volunteers; volunteer development; 4-H project

International STEM Infusion (ISI) Approach

STEM literacy is recognized as a necessary skill for participation in the future workforce. 4-H has followed the importance of developing STEM literate youth by expanding access to traditionally STEM-based project areas like Robotics. Within these efforts, it has been acknowledged that recruiting and training STEM competent staff and volunteers is a limiting factor in expanding these types of project areas. At the same time, 4-H youth are enrolled in many projects that have not traditionally been considered STEM. 4-H volunteers with increased awareness of their role in fostering STEM education and STEM literacy can be a valuable

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resource in preparing 4-H youth who possess increased STEM literacy. 4-H professionals can train front-line volunteers to use an intentional STEM infusion approach within the 4-H experiential learning process. It is hypothesized that volunteers who utilize this approach will be better able to facilitate STEM learning in real-world contexts for a wide-range of 4-H youth. Utilization of the ISI approach provides an opportunity for 4-H to develop more STEM-ready youths than recruiting youth into STEM-specific approaches alone.

Preparation of youth in STEM (Science, Technology, Engineering, and Math) is not just about preparing youth for careers as computer programmers or rocket scientists; it is about preparation of youth that are able to think in an organized, logical, and systematic way (Kennedy & Odell, 2014; Shinn et al., 2003; Wells, 2015). The call for more STEM education has caused K-12 and postsecondary education to focus on ways to improve these areas of instruction (Basham & Marino, 2013; Wells, 2015). 4-H youth development programs have also chosen to focus on this program area, with an emphasis on expanding projects like Robotics (Nugent, Barker, Grandgenett, & Welch, 2016; Riley & Butler, 2012).

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; Moye, Dugger, & Starkweather, 2014). The experiential learning model has been imbued into 4-H club work with the ‘Do. Reflect. Apply.’ strategy since Kolb (1984) translated Dewey’s approach to learning and proposed that one’s ideas and thoughts are not fixed. This reliance on the experiential learning model situates 4-H programming in a unique context to teach STEM in traditional project areas that at first glance may not be obviously STEM-related.

Front-line 4-H volunteers, project leaders, and club leaders need tools to help them plan activities that highlight STEM competency development in all project areas, not just Robotics or similar STEM-specific projects. There is limited literature on the levels of science literacy among current 4-H volunteers. However, Pottebaum (2013) did acknowledge that there is a need to improve the recruitment and training of STEM volunteers. Continuing to recruit STEM volunteers to expand programs like Robotics will be essential for continued 4-H program success. But to help 4-H members learn science by doing, it will be incumbent upon 4-H programs to provide easy-to-use resources to foster STEM literacy for 4-H volunteers in other 4-H projects to guide 4-H members’ learning.

This paper proposes an intentional STEM infusion approach that 4-H volunteers can use to foster STEM literacy in non-STEM projects. The discussion will provide practical assessment tools for 4-H volunteers to identify STEM in traditionally non-STEM 4-H projects and to help 4-H youth build STEM literacy in new contexts. This new tool may enhance current programming as a mechanism to provide STEM learning to youth that may not have an innate interest in traditional STEM projects like Robotics or Rocketry.

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Experience is a Natural Way to Learn

The experiential learning framework explains that a learner is working through the experience, finding needed information, considering other viewpoints, resolving conflicts, and reflecting on the process (Joplin, 1981). The reliance that leaders in 4-H programming place on the experiential learning model uniquely situates them to be able to teach STEM in traditional project areas that at first glance may not be obviously STEM-related. 4-H programs are positioned to provide real-world learning experiences through project work and by connecting learners to research-based information from associated Land-Grant institutions. Bringing members into an authentic situation (Mayer, 1999), such as a 4-H project, can place them in the middle of real-life and complex problem that leads to experiential learning (Lindsey & Berger, 2009). As 4-H youth search for the information and skills that are needed to solve problems, they should be engaged physically, mentally, and emotionally (Joplin, 1981). Learning requires the brain to be active (Joplin, 1981) and adaptive (Kolb, 1984). Physical, hands-on activity alone does not guarantee learning (Mayer, 1999). Through critical analysis, reflection, and experimentation, a youth may develop his or her own understanding that makes sense (King & Kitchener, 1994) within the situation of the 4-H project. As 4-H members adapt their prior knowledge to accommodate their new understanding, they develop their creativity, problem-solving, and decision-making, and can apply the scientific method (King & Kitchener, 1994; Mayer, 1999). With practice, these skills will become habits of the mind (Kolb, 2014).

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 the real world and academic knowledge (Beard & Wilson, 2002). 4-H youth in traditionally non-STEM projects can experience the extended benefits of STEM education when STEM characteristics are identified in those activities. STEM education has five characteristics: (a) there has to be a context that holds STEM elements, (b) the activity needs to be practical or authentic, (c) there are abundant opportunities for critical thinking and problem solving, (d) the activity is learner-centered, and (e) technology is used regularly in the learning context (Robinson, Westfall-Rudd, Drape, & Scherer, 2018).

Context gives learning meaning and puts STEM skills and knowledge to use in everyday situations (Driscoll, 2005). Learning to apply STEM skills and knowledge in real-life situations results in STEM literacy (Bybee, 2013). Working in real-life situations brings authenticity to learning experiences (Zollman, 2012). Authenticity is more than doing hands-on activities. Activities and problems that are authentic are open-ended, rely on the context of the situation, and will likely have multiple paths to a solution (Foutz et al., 2011; Laboy-Rush, 2011). Authenticity helps youth engage in the activity and find relevance to real life (Shinn et al., 2003).

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Context gives learning meaning and puts STEM skills and knowledge to use in everyday situations (Driscoll, 2005). Learning through application and experience results in a stronger understanding of how the skills and knowledge of STEM can be applied to unique situations in the future (Laboy-Rush, 2011; Wiggins & McTighe, 2006). Youth need opportunities to practice critical questioning of given information. The opportunity for questioning, interpreting facts, and clear thinking directly related to a real or authentic situation supports independent thinking and the development of personal confidence (Rudd, 2007). 4-H educators and volunteers should use real situations with observable consequences to teach critical thinking and problem-solving. As a result, learners are provided immediate feedback that aids in the improvement of their skills and their content knowledge (Koedinger & Nathan, 2004; Moore & Carlson, 2012). As critical thinking and problem solving become habits of the mind through practice, the learner has the lifelong ability to always be refining and polishing the skills developed from past experiences (Cromwell, 1992).

The learner should be at the forefront of any experiential teaching situation. Context allows learners to apply important prior knowledge to a unique situation intuitively (Koedinger & Nathan, 2004; Moore & Carlson, 2012). 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). When learners are put in the center of the learning experience, they have opportunities to apply their thinking skills and to solve real problems within the authentic context.

Technology is either the tool for youth to apply their knowledge or the product of youth applying their knowledge. Technology includes not only computational technology but also tools that assist in solving a problem (Sanders, 2009; Zollman, 2012). The bridge between finding technology that provides efficiency in problem-solving and designing that technology is where STEM learning is strongest. When learning by doing, using technology is often a natural conduit for youth to apply their critical thinking skills. This critical thinking process often occurs intuitively as youth find an easier way to address a problem.

As learners explore STEM education, the goal is to achieve STEM literacy so that they have skills to approach unique, complex, and real problems with confidence. Moreover, the goal of STEM education is to build STEM literacy. STEM literacy is the ability for learners to have an awareness of STEM around them in their everyday lives and the ability to apply that knowledge to solve everyday situations (Bybee, 2013). Making logical inferences, assessing whether a solution is reasonable, and knowing how to get more information when it is needed are also characteristics of STEM literacy (Kennedy & Odell, 2014; Shinn et al., 2003).

The authors speculate that the more a volunteer identifies STEM for learners, the more STEM literacy 4-H members will develop. While 4-H volunteers are experienced in planning and facilitating experiential learning by using the familiar ‘Do. Reflect. Apply’ strategy, many are not familiar with the principles of STEM education. If 4-H volunteers are provided training and

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tools for identifying STEM concepts, they can design 4-H project activities within nontraditional STEM 4-H projects for members to develop STEM literacy. This is important because 4-H youth and volunteers are active in a wide range of projects. Instead of 4-H having to invest in recruit youth into STEM projects, STEM education can be expanded because it is occurring within the projects in which youth are already enrolled. The use of the ISI approach alleviates some of the pressure to recruit experienced STEM-trained volunteers and reduces the need for recruiting 4-H youth members to participate in STEM-identified projects. Volunteers and members can be assisting in building STEM skills into their current projects.

An Intentional STEM Infusion Approach

The intentional STEM infusion (ISI) approach will help 4-H educators and volunteers emphasize and enhance STEM in nontraditional STEM 4-H project areas. This approach is influenced by the five characteristics of STEM education (Robinson, et al., 2018) and is intended to complement the experiential learning process that 4-H has historically implemented. The seven key components of the ISI approach are delineated with an explanation of each key component, then followed with a discussion of how a front-line educator, which we have envisioned as a 4-H volunteer, would implement each component, and how a 4-H member would experience each component.

STEM Problems and Activities are Identifiable in the Project Work

Explanation. 4-H members often participate in projects because they have a genuine interest in the project or topic. The real-world, direct application of skills and knowledge that are characteristic of 4-H provide a natural outlet to identify problems that need solutions. This provides a source of activities that require members to actively engage, mentally and/or physically, with the context of the project. As problems are addressed and activities have members “doing,” members are required to problem solve or think critically as they work to create, design, or apply their skills and knowledge.

Volunteer actions. The 4-H volunteer should highlight when youth are doing science, technology, engineering, and math while working to solve problems and applying their knowledge during project activities. By highlighting this use of STEM content, the volunteer makes it obvious to members that STEM is present in the identified problem or well-designed activity. Making the connection between how STEM content is applied in the context of a real-world problem puts the volunteer in the position of facilitating to develop members’ STEM literacy.

Member experience. In application, a volunteer who is leading a Clothes You Make Project might work with a member that picked a pattern that was not the right size. The member has an authentic problem to address and one that will need STEM skills to solve. Engaging with STEM concepts, the member will apply his or her knowledge to design and resize the pattern utilizing

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math and engineering skills. With the assistance of volunteers, the member will be able to recognize, engage with, and then acknowledge their developing STEM literacy.

Science, Technology, Engineering or Math Help Reach the Activity and Project Goals

Explanation. Identifying STEM concepts that work alongside activities that will meet the goals of the project brings authenticity to the work members are doing. The authenticity makes the connection between the STEM concepts and the work related to the project obvious and relevant to youth. It is important to stay focused on the project's goals when identifying STEM concepts. If the science, technology, engineering, or math is not naturally present, then it should not be forced. However, STEM can naturally and organically be included in various project types.

Volunteer actions. Initially, STEM components may not be obvious to 4-H volunteers. These follow-up questions will help volunteers identify the application of STEM in their projects:

- Can youth make changes to make the work easier?
- Can youth use science concepts in the project?
- Can youth use tools or technology?
- Can youth use math in the project?
- Can youth design something?

For example, when facilitating a bread project, the project leader could ask members to disassemble the kitchen stove to learn about how the stove works. However, this activity, while STEM-related, does not contribute to the project goal and therefore is not a recommended strategy. Instead, volunteers could plan to lead youth in using varied temperatures of water to investigate the differences in how bread rises so 4-H members can better understand what affects the reaction of the yeast in the bread making process.

Member experience. In application, a 4-H volunteer leading a Bread Making project might ask members to research where chemistry exists in the bread-making process, or how technology influences the bread making process, or how engineering can improve the bread making process. As a result of their research online or at the library, youth will identify that reactions between the yeast and sugar cause the dough to rise. Asking members to double the recipe requires accurate math. Then asking the question, "Can youth make changes to make the work easier?" could facilitate the 4-H members' consideration of alternative cooking methods.

Materials, Tools, and Activities are Selected from Real-Life Application

Explanation. Using materials, tools, and other resources that are directly related to the project and that members would use in their own lives creates authenticity in the activity. When members gain experience with real-life resources in activities that are directly related to the project goals, the authenticity of the experience helps make connections to what is learned and

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the member's own life. These connections help build confidence in using the tools, materials, and knowledge in new situations. The use of tools and manipulation of materials is a hands-on application of engineering and technology.

Volunteer activities. Volunteers should gather the tools of the trade, provide members with real, unaltered materials that relate to the project, and plan activities that use those resources. Returning to the bread project, the volunteer should provide members with the ingredients in their original packaging that can be purchased from a local grocery store. Volunteers should plan activities that require members to use the ingredients, read the labels, and possibly try alternative mixing methods to determine best results.

Member experience. In application, members should be experiencing the authentic tools and materials in their project work. Instead of simplifying activities and removing youth interactions with the tools, make time to train the youth to use the equipment necessary. The tools used and the project activities will need to be matched to the age of the youth engaged in the activity. In the effort of ensuring STEM education, it is important to keep youth interacting with the tools. But to ensure youth safety, STEM-infused lessons will need to be adapted to the age of the youth, including potentially greater supervision, training, or selecting projects that utilize appropriate tools. For example, in a woodworking project, youth under a certain age and experience should not be using many power tools on their own. However, youth are not able to build their experience with science, technology, engineering, and math without being around, involved with, and helping complete the work that is being done. They can become familiar with technology by observing appropriately modeled use of the equipment by older and more experienced youth and adults.

Multiple Methods or Variations for Ability Levels are Offered in the Activity

Explanation. This component is not innately about STEM; however, it is important to acknowledge that members of different ages and experiences are going to have different levels of capacity, skills, and knowledge about the project topic and the STEM concepts that are identified in the project activities. Being prepared for members' varying ability levels with alternative methods and variations in the engagement of the resources and materials will keep members engaged in a way that is most appropriate, meaningful, and relevant.

Volunteer actions. A volunteer should identify the different capacity levels before project work begins. Finding support for members that need extra help to work through the STEM components may be as easy as planning for more one-on-one assistance or intentionally assigning groups. To provide a greater challenge for academically strong members, a volunteer may provide the members with a problem related to the project and let them begin working with the resources provided to find a solution that makes sense.

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Member experience. Even a Clover Kid (or Clover Bud), youth ages 5-7(8) years old, can engage with STEM if the content is supported appropriately. A teenage youth and a Clover Kid could be participating in the same project but should not be doing the same activity. In an arts and crafts project, Clover Kids might be asked to assess which of four drawing utensils are most appropriate for a specific drawing activity. Teen members may be asked to pick four from the available supply of drawing utensils. Both members would be asked to explain why they have chosen and ranked the utensils. The expected level of analysis, prior knowledge, and experience would be significantly different for each youth. Following this engagement activity, each youth would be then be asked to complete a project following differentiated expectations that have been altered to their level of knowledge or experience. In this example, youth are engaging with the scientific process; they are forming a hypothesis, testing it, and analyzing the results. Older and younger youth are doing similar project work, but the activities become significantly different because of the tailoring of expectations and previous knowledge.

Identify Aspects of the Activity that Would Expose 4-H Members' Gaps in Knowledge

Explanation. Through open-ended and exploratory questioning, volunteers will be able to determine what members may be familiar with and what may challenge them. This opens the door to using members' prior knowledge to get project activities off the ground in interesting ways. Activating prior knowledge helps members make stronger connections with the new information they learn in the activities, thus making the transfer of new and old knowledge more likely in new situations (Evans, 2002; Linn, Clark, & Slotta, 2003; Ricketts & Rudd, 2002). Being aware of members' gaps in knowledge will prepare volunteers to plan activities that will provide members with opportunities to think critically and ask questions to learn more.

Volunteer actions. Identifying gaps in members' knowledge gives volunteers the opportunity to think critically and to seek out the deeper components of the projects they facilitate. Deeper components are the STEM aspects that are under the surface of the activity– they are the underpinning concepts that both the volunteer and the member may not fully understand. However, if the volunteer and member explore the projects STEM-based concepts together, then there is an opportunity for learning to occur.

A volunteer should ask members what they know about the project and with what they are not familiar. As a volunteer reveals this information, they should ask follow-up questions about members' knowledge; these gaps can provide a roadmap for designing activities that will address these deeper components that will challenge members, and in some cases, even the volunteers. The volunteer is not expected to be the STEM expert; thus, volunteers and members learning together can be an enriching experience for all. For example, turning the tables to have members research the chemistry of yeast and sugar in the bread-making process provides a stronger STEM-literacy building opportunity for members even if the volunteer is not familiar with the process.

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Member experience. In application, a volunteer facilitating the archery component of a shooting sports project may ask members what will happen to the path of the arrow when the member changes the angle of the arrow's trajectory by dropping or raising the arrow tip or how the resistance of the bowstring changes the velocity of the arrow. As members provide answers to this question, the volunteer will have fodder for follow-up activities that will help the volunteer design activities to investigate the path of an arrow. The volunteer's questions pique members' interest and draw attention to what they already know about shooting sports and how the member is applying their prior knowledge to the situation.

The Project-Leader Can Recognize Opportunities During Project Work to Foster Critical Thinking

Explanation. Critical thinking and problem solving become habits of mind through practice and application. The 4-H project provides an interesting context for members to consider many STEM aspects related to the project. Volunteers can designs opportunities that challenge members to think more about what they already know about the project topic. In these opportunities, members need to think about how to apply their prior knowledge and experience, consider alternatives, or investigate new ideas or methods. Working in the context of the project provides a real situation for members to apply their thinking and see the consequences of their decisions. The immediate feedback may inspire members to ask their own questions and seek out more information they find interesting, prompting youth to take ownership of their growing knowledge.

Volunteer actions. Volunteers should use critical questions as a way to help youth find the gaps in their knowledge. Volunteers should also create space for youth to ask their own critical questions: Why did this work this way? How can this be better? When I do this, what else could happen? Using these questions to design activities that are related to the project, volunteers begin to create a dynamic experience to build members' critical thinking skills as they work within the context of a project that members find intrinsically interesting.

Member experience. During this critical thinking process, youth monitor their own learning and self-evaluate their project work as well as their understanding of STEM concepts. As a result, this leads to an increase in STEM literacy.

Revisiting the previous archery project, the volunteer has designed an activity that asks members to investigate how an arrow travels from different distances and how the set-up trajectory changes that path. Members approach this activity as an investigation by collecting data, making conjectures, and drawing conclusions, thus exercising the scientific method as they continue to learn and hone archery skills. Through the process, members are required to consider what happens as they shoot, why changes in their aim cause different results, and how they can justify their thinking about those questions. The members are asking good questions and thinking critically as they work through the volunteer-designed activity.

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Prepare Opportunities to Reflect on the Connections Between STEM Concepts Applied During Project Work and Real Life

Explanation. 4-H project work is an integrated learning environment where youth can explore STEM topics that apply to the real world. Project work is chosen by youth and completed by youth, providing an authentically motivated context for applying STEM. This youth motivation allows an opportunity for youth to apply formally-learned academic STEM knowledge to these activities. However, this application may not occur without first being facilitated by the volunteer. At the same time, new concepts learned from 4-H project work should be connected to academic knowledge and non-4-H project experiences. When youth can take STEM concepts and apply them in unique situations, the goal of STEM education—STEM literacy—has been achieved.

Volunteer actions. A volunteer can promote reflection in many ways. Simply concluding an activity with the simple question, *"What did you learn today?"* may be enough to promote members to reflect on what they learned. Preparing activities that build in opportunities for members to talk to one another about their experience or bringing in new or young members as a recruiting session with the current project participants also can be effective ways to provide R opportunities.

Member experience. Volunteers facilitate the opportunity for members to talk about their experience, what they learned, how they will use that knowledge and skill in the future, how what they learned could help others, or when they will be able to apply what they learned in new ways. Invitations to present new ideas or showcase what was learned provide members with an outlet to reflect on their learning and begin to realize the application and relevance of their new knowledge – thus realizing their STEM literacy.

Implementation

For volunteers to utilize the ISI approach, it needs to be outlined in a way that is approachable for 4-H volunteers and 4-H professionals alike. 4-H volunteers and professionals can use the ISI approach during the program planning stages. Additionally, they can design activities in the project work with the approach. The seven key components can be considered through the following eight questions:

- Is the project activity problem- or activity-based?
- Are there connections between project work and STEM topics?
- Is the STEM that youth are going to be asked to do connected to the project goal?
- Are the resources used authentic?
- Are 4-H members encouraged to seek out more information related to STEM topics in the project?
- Are activities offered with multiple methods or variations for ability levels?

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- Are 4-H members encouraged to ask critical questions about the project and STEM?
- Are 4-H members asked to relate learning to their own non-4-H project experiences?

Working through the eight questions will allow volunteers to craft activities in their project work. Additionally, exposing where STEM exists and how to highlight it is the objective of the ISI approach. The more STEM is identified, the more member and volunteer self-efficacy can increase as they become aware that they have actively engaged in doing STEM.

Implications and Conclusions

In the wake of the challenges of recruiting and training STEM 4-H volunteers, 4-H professionals and volunteers can use the ISI approach to better identify STEM-learning opportunities and plan how to apply and integrate STEM-related approaches to traditionally non-STEM projects. 4-H volunteers have the opportunity to identify STEM in traditionally non-STEM 4-H projects to help youth build STEM literacy. This change in practice by volunteers will enhance current programming to deliver STEM learning to youth that may not have an intrinsic interest in traditional STEM projects.

Identifying STEM in traditionally non-STEM projects provides an opportunity to introduce STEM learning to non-STEM oriented youth. Expanding the focus on STEM beyond traditional STEM projects allows 4-H to increase the number of youth engaging with STEM in authentic contexts to continue to enhance formal or academic STEM knowledge. This exposure could lead more youth to develop STEM literacy. An increase in STEM literacy prepares more youth for STEM careers leading to the potential for more youth to consider careers in STEM and STEM-related fields.

The authors posit that the proposed ISI approach can be used by 4-H volunteers to foster STEM literacy in non-STEM projects. The fundamentals of this approach have been introduced here. This approach has been shared so that practitioners across the country can implement the approach so that it may benefit from the refinement that comes from practitioner implementation and the resulting revision from application and research.

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