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Article

Integrated STEM: Focus on Informal Education and Community Collaboration through Engineering

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Abstract: This article showcases STEM as an interdisciplinary field in which the disciplines strengthen and support each other (not as separate science, technology, engineering, and mathematics disciplines). The authors focus on an open-ended, complex problem—water quality—as the primary teaching and learning task. The participants, middle school female students (aged 9–15 years), interacted in an informal educational setting (i.e., Girl Scouts) on a research project investigating river quality following the river's restoration. The community, including Girl Scout participants, leaders, parents, university faculty, graduate students, and others, utilized an action research (AR) approach when interacting with the participants. Methods such as observational field notes, focus groups, and collected artifacts were commonly employed. The authors describe the history of STEM and AR leading to authentic science research projects through eight engineering skills/practices (incorporating science, technology, and mathematics) and showcase participant interactions, implementation, and community engagement in the STEM water quality river project. Findings indicate that informal engineering based projects can serve as opportunities for participants to connect with integrated STEM. Implications include the need for engaging participants in informal authentic science to support traditional school STEM learning and encouraging community engagement in integrated STEM to support traditional K-12 classroom instruction.

Keywords: informal education; science education; engineering education; integrated STEM; water quality; Girl Scouts; authentic science, NGSS; problem-based learning; community engagement; social justice

1. Introduction, STEM History, and Action Research

As a world community, the importance of STEM is currently ubiquitous [1–3]. In the US, the science, technology, engineering, and mathematics (STEM) education movement began approximately two decades ago, with one of the first explicit uses of "STEM" being in 2005 [4]. Often, the idea that the four disciplines are intertwined is lost, as science or mathematics is pulled to the forefront of a discussion or classroom. Yet, studies show that true integration of the four disciplines is a powerful student learning tool [5–7]. In order to explore the learning tool of authentic science [8–10] in a water quality project most effectively, an understanding of where we have been and where we are going as a

STEM community, or the evolution of STEM, is beneficial and situates the context. Note that the term authentic science [8–10] is used purposefully, and is compatible—but distinct—from problem-based learning and other pedagogies. In this article, the authors define authentic science as participants working in the natural world, working towards a problem, exploring information, using technology, utilizing mathematics, analyzing evidence, developing conclusions, refining questions and methods for future use, communicating results, and recording the results and disseminating information for others to use [8–10].

The educational revelation of STEM took a few turns before settling into its current position. By the 1940's, many of the approaches of the Progressive Era had been collected into an approach referred to as "life adjustment education" [11] (p. 251). By the 1950's, these collected approaches were viewed with disdain by the general public. The launching of Sputnik by the Soviet Union in 1957 was perceived by many to be a failure of the United States, "While American schoolchildren were learning how to get along with their peers or how to bake a cherry pie . . . Soviet children were being steeped in the hard sciences and mathematics needed to win the technological race . . . " [11] (p. 266). With Sputnik, the roots of American fascination with STEM education were planted deep, and have been producing fruit ever since. The first fruits were in laws such as the 1958 National Defense Education Act which created the need for "new math" and "new science" in American high schools. Further fruit emerged with the 1983 publication of "A Nation at Risk" [12], in which among its hyperbolic attacks were recommendations that all high school students be required to take three years of math, three years of science and one year of computer science.

In the 1990's, the National Science Foundation (NSF) first began combining the fields in their shorthand [13]. The unfortunate first acronym was "SMET" (science, mathematics, engineering, technology); however, a program officer complained of the sound, and thus "STEM" emerged as the acronym of choice [13] (p. 20). In the 21st Century, economic concerns took center stage. While the 20th Century focused "on the relationship between STEM education and national prosperity and power", by century's end, the US was reaping both military and economic advances made possible by developments in STEM education and, as such, "widespread STEM literacy, as well as specific STEM expertise" should be considered "to be critical human capital competencies for a 21st century economy" [14] (p. 1).

Sputnik was not finished producing fruit in the new millennium; in 2007, the National Academies published *Rising Above the Gathering Storm* [15], a report that once again warned citizens and their leaders of the weaknesses in US STEM education. This report led to the passage of the America Creating Opportunities to Meaningfully Promote Excellence in Technology, Education, and Science Act of 2007, otherwise known as America COMPETES Act, which provided funding to government agencies and schools on all levels to improve STEM education. The Act was reauthorized in 2010 (and passed unanimously by the Senate). Likewise, US Common Core Standards [16] focusing on mathematics and language arts appeared in 2009 and new US standards for science called the Next Generation Science Standards (NGSS) that included engineering skills and practices were released for public comment and eventual adoption [17]. In 2013 a new name for technology standards (originally called National Education Technology Standards) emerged named the International Society for Technology Education (ISTE) [18].

At present, US K-12 STEM teachers are expected to utilize all three sets of standards when planning, implementing, and assessing students. Accepted school policy most frequently puts the burden of student success and skill accounting directly on the K-12 teacher. In a difficult profession [19], this layer of intensity is often a contributing factor to the high percentage of STEM teachers that leave the teaching field [20,21]. Additionally, these same teachers are asked to utilize authentic science [8–10] and integrate STEM components in classroom instruction, without added support to enact the work.

While the burden of student success falls on the in-service teacher, it is ironic that the primary form of research that empowers the teacher—action research (AR)—is still somewhat devalued. Just as STEM education has roots in the Progressive Era, so too the roots of AR can be found in the early 20th

Century, when John Dewey presented "a vision of the teacher continuously pursuing self-education in the course of the act of teaching" [22] (p. 211). Indeed, it was Dewey who, in 1910, provided the five stages of the process of inquiry, steps that are familiar to AR practitioners:

1. The experience of an indeterminate situation, that is, disrupted equilibrium between organism and the environment;
2. The conversion of the indeterminate situation from a mere dilemma to a problem capable of articulation;
3. The establishment of hypotheses along with broadly anticipated consequences of action upon them;
4. The elaboration and testing of the hypotheses; and
5. The reestablishment of a determinate situation [22] (p. 212).

In 1917, the General Education Board (GEB) became involved in supporting early forms of AR. Over the next 24 years the GEB funded the Lincoln School, Teacher's College, Columbia University; the school was focused on producing education research by in-service teachers. By the end of the program, Lincoln School teachers generated hundreds of studies and textbooks focused both on curriculum and pedagogy. As described by Perillo [23], while teaching is "a profession where members are expected to be consumers rather than creators of knowledge, and practitioners rather than 'experts'", teachers who engage in AR can defy "many of the most foundational premises that have guided schools and the production of education research alike" [23] (p. 90).

As time went by, the concept of AR migrated from education into the world of business. As Hendricks [24] explains, leaders engaged in research involving the training of factory workers through the 1930's; however, the leaders incorporated much of Dewey's political ideology by arguing that democratic workplaces increased morale and productivity, as well as becoming a driving force in their communities.

It didn't take long for AR to make its way back into the field of education, in spite of the push for what was deemed "rigorous scientific studies" as a means of legitimizing educational research [24] (p. 7). Corey [25] wrote the seminal work "Action Research to Improve School Practices" in 1953; however, through the 1950's and 60's, AR became diffused throughout other fields such as curriculum theory and thus "lost much of its spontaneity and vitality" [22] (p. 214). By the 1970's, Stenhouse [26,27] started the teacher-as-researcher movement in England, arguing that educational research must be testable by teachers to be of use to the field. His notion gained traction internationally, spreading quickly through Australia, Canada, and the US. As the movement grew throughout the 20th Century, it became influenced by notions such as researchers becoming reflective practitioners and the evolution of participatory research; indeed, as all forms of qualitative research have gained traction, so too has AR. Action research is defined as a "participatory democratic process concerned with developing practical knowing in the pursuit of worthwhile human purposes, grounded in a participatory world view" [28] (p. 1). Thus, the participants' voices are heard. This STEM history and research context informs work in traditional classroom settings, but also informs work in informal learning settings (e.g., after school clubs, museums) that can support—intentionally or unintentionally—traditional K-12 classrooms.

2. Methods and Analysis

During fall 2015 and spring 2016, the second and last author, with assistance from Girl Scout leaders and parents, supported a group of 10 middle school girls (9–15 years) in an informal Girl Scout setting. Although there were 14 girls that participated in the Girl Scout activities, only the results from the 10 scouts with IRB consent and assent are presented here. The Girl Scout group, led by university educators and involving community members, created a research project investigating the success of the Laramie River Restoration that was completed in 2012. The restoration site is located within the city limits of Laramie, and a primary goal of the project was to allow the scouts the ability to "be" scientists, and to have a voice (which is also important in AR projects). Mentors (defined here as university faculty, graduate students, and guest scientists) strived to show the Girl Scouts that they have the power to shape and create scientific knowledge, even at a young age. While guided by researchers' work and mentors, the scouts molded the water quality project into something that they ultimately controlled, and that they changed and adapted as the project progressed. With guidance, the scouts posed a research question and generated testable alternatives and null hypotheses. To test these hypotheses, the scouts decided to compare macro-invertebrates' diversity, riparian height, canopy cover, particle size, and river velocity between a control site and restored site.

The Girl Scouts worked over several weeks in the field and used five biological or physical factors to assess water quality. They used a control site (non-restored area) and compared that with the research site (restored area) as the Laramie River was channelized in the 1940s, leading to higher stream velocity; consequently, it was restored between 2009 and 2012. First, the macro-invertebrates found at the bottom of the river, although small, were big enough to be seen with the naked eye. Guided by mentors using research scientists' work [29,30] the scouts were taught that macro-invertebrate diversity and presence can be used to determine water quality. Second, vegetation height was recorded, as it affects both aquatic and on-shore species that rely on riparian vegetation [31]. Third, the scouts recorded the canopy cover, as a greater canopy equals cooler water and more macro-invertebrates [32]. Fourth, the scouts observed benthic particle size as compared between sites. Larger rocks were found at the control site, because the channelization of that site washes smaller particles downstream to the restored site. Fifth, the scouts noted, but did not measure, that faster-moving water tends to contain more dissolved oxygen [33], and that the turbidity of the water as gauged by particle size could be a factor. High levels of particles can decrease light penetration and thus plant productivity and lead to a decrease in quality of habitats for aquatic organisms [34].

As the second author was already vested in the Girl Scout group and the Laramie River water quality project, she began searching for ways to understand what it was that the Girl Scouts were learning in the informal setting that could inform formal K-12 education. As a team, an AR methodology was adopted. Action research is by a group and informs that group, and as such, attention was given to the group's workings including democratic participation, community empowerment, and social justice, as well as the STEM content. There were no set AR rules that the scouts or others followed; however, the scouts conducted the research, and the data informed the group. The data reported here comes from 10 Girl Scout meetings, four group discussions through observational field notes (in the field and more traditional meetings), second author reflective journaling, and an artifact (poster). Some aspects of the project, such as STEM content, received more attention than other aspects, such as social justice, which received less of a focus.

During project meetings, observational field notes were recorded, and the researcher took meeting notes on the content, topics, scouts, and dialogue that occurred. Quotes from the scouts and facilitators were recorded, with special attention being paid to scout questions and answers. Information was also recorded on the mood and actions of the scouts. After the meetings, the researchers typed up the handwritten notes and added details as memory would allow for later analysis. The researchers recorded quotes as accurately as possible in an interactive setting.

The observational field notes from the meetings and focus group discussions were color coded for themes by the researchers. They coded a broad component (e.g., science and engineering practice) and then a more specific instance of that component (e.g., solving a problem). The researchers did this taking into account the context of the meetings and focus groups. As this was an AR project, the scouts were encouraged to agree or disagree with what the researchers discovered in the data. Only the science and engineering practices from the observational field notes are shared here, although evidence of all STEM components were apparent and are referenced in the findings.

Facilitated by the second author, the focus group discussions centered on the three dimensions of learning (i.e., disciplinary core ideas, cross-cutting concepts, and science and engineering practices) from the NGSS [17]. The Girl Scouts were asked what they were learning, how they were learning it, and what they thought was-or was not-being addressed in the water quality project. Examples of questions included: (1) What are some skills (science and engineering practices) that you have learned? (2) What are some of the big topics (disciplinary core ideas) that you've talked about? (3) What are some patterns (cross-cutting concepts) that you have found? (4) What subject have you learned the most about during this project? (5) How did we analyze data? and (6) Have you discussed your ideas and results with anyone inside or outside the group, and if so, how?

The reflective journaling was utilized in the same fashion, with the second author writing about the girls' work and how they did it. Then, the researchers went through her reflections and categorized them by broad categories. The artifact poster presented here was developed by the scouts in conjunction with leader and community support. It is used as evidence of participant engagement, learning, and excitement using the participant's lens of what is important to showcase from the water quality project. For this article, 'participant' can include the scouts, faculty, and community members. Since the science and engineering practices are highlighted in this article, only those groupings are included as main sub-headings in the results, but other aspects of STEM are embedded in them.

3. Results

To begin, the Girl Scouts, mentored by their community (e.g., parents, leaders, other scouts, undergraduate students, graduate students, researchers), conducted a hypothesis-driven research project that found that the Laramie River restoration project improved water quality at the site. The river's macro-invertebrates showed increased diversity, the riparian height and canopy cover had increased, and water levels were shallower with higher velocities. Although not the main purpose of the article, understanding what the Girl Scouts studied during this project gives context to what and how they learned STEM through engineering practices. The National Research Council (NRC) [35] identified eight science and engineering practices, and the results of the community based Girl Scout water quality project are described here.

3.1. Engineering Skill: Asking Questions and Defining Problems

One of the most fundamental skills across all engineering disciplines is the ability to define and refine a problem statement. The process of developing a conscience-tractable problem statement generally requires Socratic questioning—a continuous questioning process that further reveals truths and limitations in the knowledge surrounding a particular problem. The process of Socratic questioning requires active engagement from all parties involved.

The Girl Scout water quality project gave the girls the opportunity to ask their own questions. One opportunity came at a presentation about the Laramie River, during which the questions were written on the board. The girls and community group worked to narrow down the questions into one that would be the main question. The group discussed what composes a good question and what that means. Characteristics that were discussed included considering if the question was answerable, testable, compact (e.g., not too time intensive), and measurable (e.g., are the tools available). For example, one community participant suggested that the group ask, "How clean is the water?" The facilitators then guided scouts through asking themselves whether that was measurable in the amount of time allotted, and it was determined that they needed a broader question that could be answered with a "yes" or "no". They decided that the main problem to solve became, "Was the Laramie River restoration successful or not?" The girls were encouraged to ask questions throughout the whole process. It was emphasized that questions lead to more questions, and not knowing the answer was okay. In the first of the eight engineering skills, the scouts exhibited use of science through content, technology through communication means, engineering through problem solving, and mathematics though potential data analysis.

3.2. Engineering Skill: Developing and Using Models

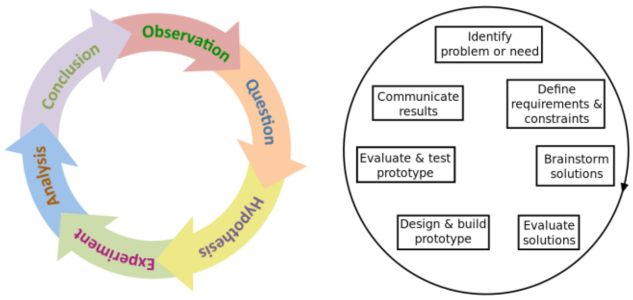
In order to effectively develop a solution or fix to a problem, engineers spend countless hours testing hypothetical solutions-in practice this requires reducing the time to test possible solutions. In order to do this, however, engineers must be able to capture the essence and relevant feature space of problem into what is commonly known as a model. Models are abstract representation of reality—the more detailed the model, the less abstract the representation (and vice-versa).

The Girl Scouts used the riparian ecosystem model as it related to the Laramie River. Along with the university and community leaders, they viewed a "holistic" image of the region. At the beginning of the project, the scouts were limited in their scope of what a river actually was, and when asked, said that it was "water". The leaders worked to emphasize that the river was more than water and it included vegetation, sediments, flora and fauna inside the water, animals in and out of the river, and more. By the end of the project, when asked if models were used, a scout stated, "Yes! We looked at a model of a system the whole time, because the river is a system, and so it's a model!" A dichotomous key was used frequently to identify macro-invertebrates, and the Girl Scouts were able to categorize the macro-invertebrates based on the number of tails, legs, shape, and more by using the model of macro-invertebrate families. The scouts represented data in graphs and charts that showcased varying aspects of the riparian ecosystem model. While some scouts enjoyed data analysis in the form of identifying macro-invertebrates, others preferred creating graphs and charts over working with insects. At one meeting, one scout asked, "When are we going to make more graphs and analyze data that way? That was really fun!" In the second of the eight engineering skills, the scouts exhibited use of science through content, technology through communication means and potential tool use, engineering through problem solving, and mathematics though potential data analysis and river modeling.

3.3. Engineering Skill: Planning and Implementing Investigations

With a problem and a model defined, engineers must then design an effective search through potential solutions. These investigations must be well planned and executed-failures during this process are not only expected they are critical in engineering process. While multiple approaches exist, developing and implementing investigations that are 'fail-fast' is an ever-growing trend within engineering design. Early-career engineers are often shielded from the planning stages of larger-scoped projects, rather being trained through experience in planning and implementing smaller sub-component investigations.

The entire Girl Scout program revolved around the scouts actually doing their own research and following their own questions about water quality. The leaders engaged the scouts in the basic steps of the scientific process (Figure 1a) and the engineering process (Figure 1b). During the first meeting, facilitators engaged the girls in discussions about the scientific process, and they referred to the processes throughout the water quality project. The scouts determined their hypothesis: "Was the restoration successful or not?" Failure could include an unchanging river because the river did not improve. Data that they collected was vital to determining the project's success, such as "Mayflies, they can show us how polluted the water is". The girls ultimately decided on which data-collection tools would function the best and provide the best information on the river. When the group was stuck, the leaders guided the Girl Scouts towards appropriate measures. They worked over several weeks to collect water-quality data using procedures that they helped to select, and they determined number of samples, where to sample, how to sample, and then how to analyze these data. One parent noted the importance of learning these skills early on in life, "She understands the scientific process and it will help her in future science classes and perhaps her career." In the third of the eight engineering skills, the scouts exhibited use of science through content interactions, technology through communication and tool use, engineering through problem solving, and mathematics though data collection, potential analysis, and river modeling.



(**a**) (**b**)

Figure 1. (**a**) Simple Scientific Process; (**b**) Simple Engineering Process (both images labeled for reuse by commons.wikimedia.org).

3.4. Engineering Skill: Analyzing and Interpreting Data

What is success? Engineers use data to determine when they have solved a problem sufficiently—given the requirements and investigation plan. Data does not have a voice, it must be analyzed and interpreted; the same data, under different investigations and context, may yield vastly differing interpretations. Determining 'reality' is not trivial, but can be grounded in context, as long as the prior three engineering skills have been adequately addressed.

The Girl Scouts spent several weeks learning appropriate ways to analyze their data. While the scouts did not perform computer-programmed statistical tests, they were shown how the programs worked and how to interpret and explain the results of these tests. Most of the data analyses completed by the Girl Scouts was in relation to the macro-invertebrates. The scouts sorted macro-invertebrates by family (as identification to species is quite difficult) using ice cube trays and field guides, and they counted the number of each family in order for facilitators to help them determine the diversity of macro-invertebrates at the two sample sites. The scouts learned to differentiate between families based on body parts. One scout asked the second author, "If this bug has two tails, then it has to belong to one of these two families, right? Unless it's missing a tail, then it could be a whole different family!" They then created graphs based on the water quality data collected including temperature, macro-invertebrate diversity, vegetation cover, tree height along the banks, velocity, and sediment size. Learning how to interpret these data took several meeting sessions and to show competence the girls-individually and in groups-explained the data results to each other and to an audience of graduate students as well as family and peers. In the fourth of the eight engineering skills, the scouts exhibited use of science through content interactions, technology through communication means and tool use, engineering through analyzing and interpreting, and mathematics though data analysis and river modeling.

3.5. Engineering Skill: Using Mathematics and Computational Thinking

What differentiates today's engineering from that of ancient Egypt are advances in technology. Both mathematics, and the ability to compute, existed almost 5 thousand years ago (2700 BC), with various tools such as the abacus. The mechanisms of how to use mathematics and computational thinking to solve problems has changed, but the foundations are the same. Using models, measurements, and the data available, transformations are developed that convert the raw data into useable information. The Girl Scouts used simple mathematics to count the number of individuals in macro-invertebrate families from the water samples. One group of scouts had hundreds of midges to count during one meeting session. Though the process of counting them was simple mathematics, it was instrumental in determining diversity later on. The graphs that they created explaining the water quality parameters showcased basic number competency. The statistical programs, such as the *t*-test, were explained by the scouts before they produced graphs and charts that showed their understanding of the results. Several scouts also helped the mentors to weigh the dried plant matter removed from the macro-invertebrate samples. This process required subtracting the weight of the tins holding the plant matter. One scout asked "Why are the samples so heavy? There's hardly any plant matter actually in them". The second author nudged them to think that they weren't only weighing the plant matter. The same scout then understood, "The tin! I forgot about the tin that the plants are in!" In the fifth of the eight engineering skills, the scouts exhibited use of science through content, technology through communication means and tool use, engineering through computational thinking, and mathematics though data analysis and modeling.

3.6. Engineering Skill: Constructing Explanations and Designing Solutions

From a problem, to a model, to experiments, to data collection and analysis—if an engineer does not design a solution, the prior work is all for naught. After the analysis of data, collected from a well-designed investigation to solve an existing problem-engineers must construct an explanation for the cause of a problem (or a solution to the problem). Once the cause is known, a solution must then be designed and validated.

The Girl Scouts used the data and statistical tests to evaluate whether the Laramie river restoration resulted in better stream health at the restored site versus the control site. Although it seemed simple in the beginning, the scouts quickly realized that "healthy" was complicated to define. As they analyzed the data on temperature, number and diversity of macro-invertebrates, and other data, they decided on whether or not they thought that the river was healthy. This determination would lead them to the answer to the original question in regard to the success of the restoration. There were conversations with other scouts, leaders, and community members that led to conclusions about the current health of the river and the future direction for future restoration efforts as well. In the sixth of the eight engineering skills, the scouts exhibited use of science through content explanations, technology through communication and tool use, engineering through designing and showing solutions, and mathematics though data analysis and river modeling.

3.7. Engineering Skill: Engaging in Evidence-Based Arguments

Engineers cannot operate on belief. They rely on evidence, generally constrained and limited to the bounds of the models and investigations they have developed. The analysis of the data, through mathematics and computational thinking, enables engineers to quantify and express arguments based on numerical evidence rather than anecdotal beliefs.

The scouts engaged in and promoted evidence-based answers. The Girl Scouts actually disagreed on the answer to the basic question of the success of the river restoration. Each scout took a turn describing to their peers and mentors which of their hypotheses were best supported by their data. Many discussions took place about data such as temperature (e.g., What is the "perfect" temperature for the Laramie River?), macro-invertebrates (e.g., Is it better to have more overall macro-invertebrates or better to have more species-with a less overall total-of macro-invertebrates?), and velocity (e.g., If the water's velocity is too fast, will it kill the macro-invertebrates?). When the last author asked "You recorded more diverse stream velocities in the restored site than the control site. How might this observation be a factor in stream health?" one scout responded saying, "Different flows might provide a variety of little habitats for different macro-invertebrates. This would mean the restored area is better for them". The last author remembers this well, as he told the scout that it was a brilliant observation and then excitedly, the scout turned to her mom and they gave each other a "high five". When the scouts were practicing for their presentations (during a practice poster session where mentors asked the scouts questions) they answered questions which encouraged the scouts to argue and justify their conclusions. In the seventh of the eight engineering skills, the scouts exhibited use of science through content, technology through communication and tool use, engineering through evidence building, and mathematics though data analysis and modeling based on justifications.

3.8. Engineering Skill: Obtaining, Evaluating, and Communicating Information

An engineer cannot work in vacuum. An engineer relies on information; it is, in fact, at the heart of all the prior skills. While engineers may be viewed as simple consumers of information, the truth is that they are also producers. A common misconception exists that engineers "do not need to communicate". Quite the contrary; the advancement of knowledge requires explicit communication, not only of end products (solutions), but the process, success and failures encountered during every stage of the engineering design process. The ability to communicate results requires higher levels of synthesis-generally a time when engineers reach pivotal conclusions about their work-and ideas for future solutions.

The culminating event for the project was a symposium where the Girl Scouts participated in poster presentations to a community, or public, audience. Parents, Girl Scout leaders, and members of the public were invited to see the posters and ask questions. The scouts were assigned to different posters (see Figure 2) representing various stages in the Laramie River water quality research project that reflected the scientific and engineering processes. They presented findings as scientists and engineers. Facilitators also emphasized that scientists can communicate their information informally, simply by talking to their friends and family about what they did. When asked if they needed to coordinate a big presentation to disseminate their work, one scout replied, "Well, to be formal yeah, and if I was a professional scientist I would write papers and such, but since I'm in school I think it's okay to just talk about it to anyone who is interested!" Although not an intended part of the project, the leaders presented their research to the head of the Laramie Girl Scouts and a select participant group travelled to Montana where they presented the research in the capitol rotunda. In the eighth of the eight engineering skills, the scouts exhibited use of science through content, technology through communication and tool use, engineering through communication and evaluation, and mathematics though data analysis and river modeling.

Through this water quality project, the scouts fulfilled the NRC's [35] vision of scientific engagement, scientific knowledge development, and scientific interest improvement while engaging in STEM. Table 1 highlights some of the participant quotes through these categories. The scouts produced a poster presentation that shows the whole water quality scientific research process. The poster artifact (Figure 2a–e) highlights the main aspect of the scouts' work and provides and insight into what the community team thought was most important to display to others.

Table 1. Quotes from Girl Scouts and community participants during the water quality project.

Girl Scout	Community Member	Researcher or Leader
"We can look at whether or not the water is cleaner and the river is healthier or not." (Scientific engagement)	Paraphrase: That this group can figure out if the river is cleaner and better is remarkable. (Scientific engagement)	"Patterns are not just cool designs that you see, but places where you notice things occurring." (Scientific engagement)
"We've seen patterns. Like how in faster water there are fewer macro-invertebrates than in slower water." (Scientific knowledge)	Paraphrase: I want to know more about these terms that the girls are using. I mean, riparian height, just wow. (Scientific knowledge)	"Why would the restoration team put bigger rocks along the bank of the river?" (Scientific knowledge)
"When are we going to make more graphs and analyze data that way? That was really fun!" (Scientific interest)	Paraphrase: Watching my girl and doing projects like this one make me want to do more projects and help the community. (Scientific interest)	"We could look at plant growth around the river." (Scientific interest)

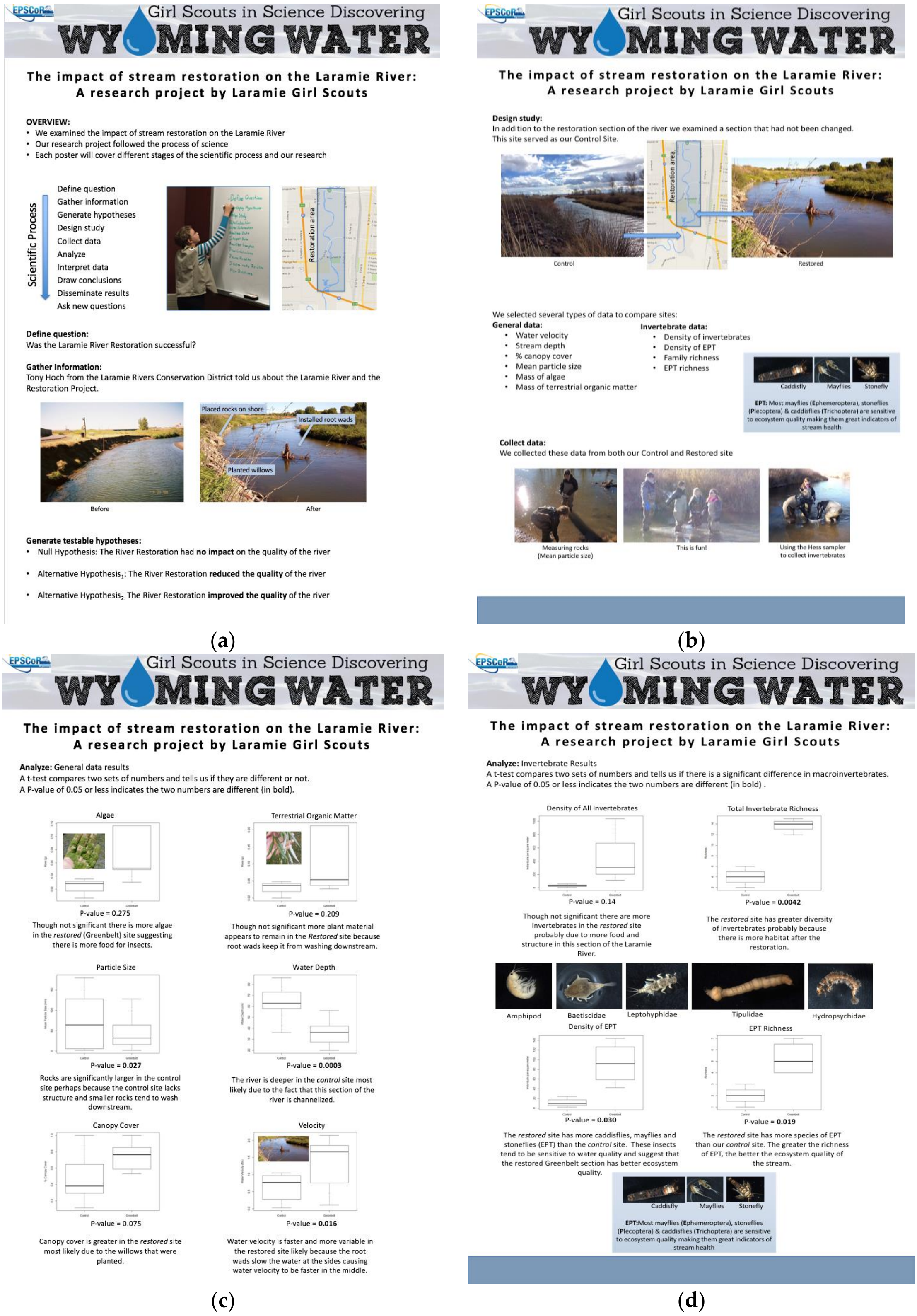
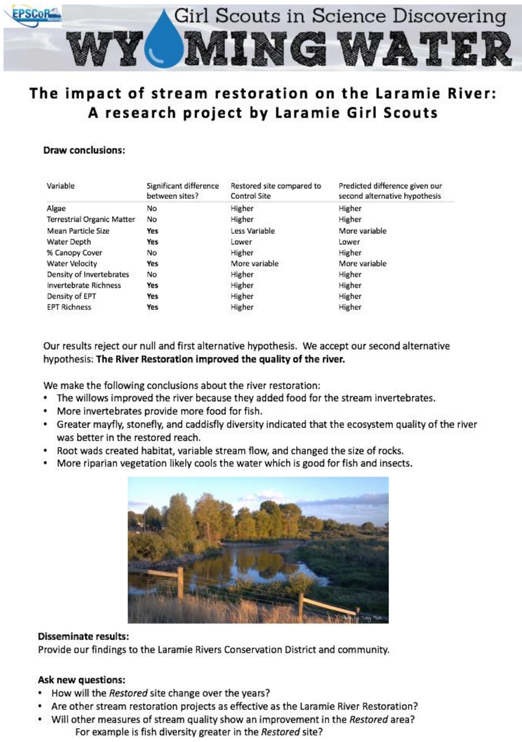


Figure 2. *Cont.*



EPSCoR

Girl Scouts in Science Discovering

WYOMING WATER

The impact of stream restoration on the Laramie River:
A research project by Laramie Girl Scouts

Draw conclusions:

Variable	Significant difference between sites?	Restored site compared to Control Site	Predicted difference given our second alternative hypothesis
Algae	No	Higher	Higher
Terrestrial Organic Matter	No	Higher	Higher
Mean Particle Size	**Yes**	Less Variable	More variable
Water Depth	**Yes**	Lower	Lower
% Canopy Cover	No	Higher	Higher
Water Velocity	**Yes**	More variable	More variable
Density of Invertebrates	No	Higher	Higher
Invertebrate Richness	**Yes**	Higher	Higher
Density of EPT	**Yes**	Higher	Higher
EPT Richness	**Yes**	Higher	Higher

Our results reject our null and first alternative hypothesis. We accept our second alternative hypothesis: **The River Restoration improved the quality of the river.**

We make the following conclusions about the river restoration:
- The willows improved the river because they added food for the stream invertebrates.
- More invertebrates provide more food for fish.
- Greater mayfly, stonefly, and caddisfly diversity indicated that the ecosystem quality of the river was better in the restored reach.
- Root wads created habitat, variable stream flow, and changed the size of rocks.
- More riparian vegetation likely cools the water which is good for fish and insects.

Disseminate results:
Provide our findings to the Laramie Rivers Conservation District and community.

Ask new questions:
- How will the *Restored* site change over the years?
- Are other stream restoration projects as effective as the Laramie River Restoration?
- Will other measures of stream quality show an improvement in the *Restored* area?
  For example is fish diversity greater in the *Restored* site?

(**e**)

Figure 2. Water quality project: (**a**) Introduction of problem for water project; (**b**) Procedures of the water quality project; (**c**) Results and analysis (part 1) of water project; (**d**) Results and analysis (part 2) of water project; (**e**) Conclusions and future directions of the water quality project.

Moreover, paraphrased community comments during meetings, in the field, and during the final poster presentation are presented here as evidence of the scientific engagement, knowledge building, and interest. Table 2 highlights these STEM authentic science remarks:

Table 2. Paraphrased integrated STEM, water quality quotes from community members at public events.

Community Member Scientific Engagement	**Community Member Scientific Knowledge**	**Community Member Scientific Interest**
This program really allows everyone to be involved and working on different aspects of a project at the same time. It's very different than science done in schools.	Wow, these girls really know their stuff. Some of this is high level water quality data that I didn't learn until college."	I've never seen my daughter this interested in bugs before! We've had to look for insects in the backyard at home to compare them to the macros"
How much was [the scout group] involved in the process? The girls answered saying that they all had the chance to participate every step of the way by making choices about what data was collected, how it was collected, what the presentation should look like, who would present each part, etc.	My daughter knows more about water quality than I do.	My daughter is starting to question the quality of water everywhere, even in puddles!
	She understands the scientific process and it will help her in future science classes and perhaps her career.	She now wants to participate in all of the citizen science opportunities at the University like moose day, and the RM amphibian project.

Lastly, community participation was evident in this water quality project, and democratic participation was shown at every meeting, field exercise, and focus group. Participants spoke freely during meetings often without raising a hand, and this trend held during the field experiences and focus group sessions. The authors discussed the social justice aspect of the STEM water quality project, and Bonnycastle's [36] definition that social justice creates a safe environment for living, contributing, and thriving as individuals and groups was used. The first two authors most often conversed about the girls' access to the Girl Scout group and outings as the main barrier to a socially just grouping. Yet, conversations turned to water quality as a social justice issue as well. The second author once stated, "If the participants find out that water quality is low, then they could take action since [water quality] affects other areas of their lives such as wellbeing". There seemed to exist a slight tension between STEM content data collection and social justice dialogue. Historically, there has been some tension between STEM research and the assistance STEM has previously received from political, military, and economic interests. Who had access to the STEM information, the ability to join the scout group, and why those issues mattered was discussed, but did not hold a prominent place in this work.

4. Discussion and Conclusions

As the purpose of this article was to show the importance of STEM integration using authentic science, the evidence presented highlighted eight identified engineering principles that incorporated the other science, technology, and mathematics disciplines. The Girl Scouts and community members were fully immersed and experienced a true, integrated-STEM, authentic science project. The authors identified this water quality project as authentic science, or integrated STEM project, because it met the definition of participants working in the natural world working towards a problem, exploring information, using technology, utilizing mathematics, analyzing evidence, developing conclusions, refining questions and methods for future use, communicating results, and recording the results for others to use. The individual STEM components of the data can also be clearly identified.

The enormous amount of STEM integration in this type of community project shows the interdisciplinary work and how each discipline strengthens the other. The use of science content is evident in the project itself and the scouts' interactions and comments in regard to the scientific content. The artifact poster also showcases the STEM content (e.g., terrestrial organic matter, particle size) that the scouts utilized in the authentic science experience. The use of technology is shown through simple and complex means including: whiteboards, PowerPoints, Hess samplers (to collect invertebrates), statistical analysis software, scales, and more. Again, this is highlighted in the artifact poster. Engineering was shown through eight identified NRC [35] parameters (outlined earlier in this article) and included factors such as asking questions, defining problems, developing and using models, planning and implementing investigations, analyzing and interpreting data, using mathematical and computational thinking, constructing explanations, designing solutions, giving evidence-based arguments, finding and evaluating evidence, and communication of information to others. Without direct instruction on what types of data should be found on the presentation, the scouts showcased all of the engineering skills. The artifact poster (Figure 2) emphasized these various pieces. Quotes were offered to support the concepts of scientific engagement, knowledge, and interest. It was impossible for the authors to deconstruct the quotes and put them into one discipline of STEM since the community members and scouts spoke about the content and project as a whole. The whole project included pieces from each STEM discipline, and each was emphasized.

As an AR project, this was a rich community based STEM project that brought university instructors, graduate students, researchers, parents, Girl Scouts, and other interested parties together. Meetings were open and the conversations and quotes that were recorded showed the depth of knowledge and STEM interest that this project was built upon. Community participation was evident in this water quality project as the number and type of participants varied in each meeting or field setting, and there was significant community involvement in the culminating presentation. It also sparked community interest in other events and programs; as one parent stated, "Watching my girl, and doing projects like this one, make me want to do more projects and help the community". Democratic participation was a part of every meeting and in the field as each person had a voice and the power to express their opinion. When a community member asked a scout at the final presentation how much everyone was involved in the process, the girls answered saying that they all had the chance to participate every step of the way by making choices about what data was collected, how it was collected, what the presentation should look like, and who would present each part. Critiques of the process were heard from all of the involved parties, as mentors were interested in how to improve upon the program in future years, and felt it was important to understand different viewpoints. The social justice aspect of the STEM water quality project was discussed, but only minimally addressed. The research team thoughtfully engaged in dialogue relating to community member access of the Girl Scout group (e.g., information, transportation, uniform), and how access could allow for or block engagement with the process. Conversations involving future projects and means of reaching underrepresented groups in the Girl Scouts took place over several days throughout the year.

This study further validates previous studies' findings that STEM integrated with authentic science projects engages learners. Where this study adds to the literature is in its use of an informal Girl Scout platform to showcase the STEM learning through engineering skills. Furthermore, AR, not often used for integrated STEM studies, allows for a strong participant voice in an integrated STEM project. The Girl Scouts had a voice. Hearing voices from the field allows a community to solve real-world problems, learn STEM concepts, and advance traditional K-12 learning together. Implications for educators and community members at all stages are vast. Future community project leaders could turn their attention to the STEM pieces that participants engage with during integrated projects and make note of that learning in regard to NGSS [17], Common Core [16], and/or ISTE [18] standards. Showcasing methods and standards is not a means to validate the informal integrated STEM projects being conducted, but instead to promote the concept that informal STEM education can provide the time, means, and resources for true authentic STEM learning and compliment traditional K-12 education. Where time and resources can be limiting to engage students in authentic science processes, the authors ask a question about the scouts, and all students, that participate in informal, integrated, authentic STEM projects, "Are the skills that K-12 students learn in informal settings valued in traditional K-12 settings?" The authors suggest that the answer is no, and then question, "How can K-12 educators, informal educators, and community members work together to improve the K-12 student skillset?" is crucial.

5. Limitations

This study has several limitations. The AR process was sometimes overshadowed by water quality project data collection. Hence, participant voice was "paused" so that the project could advance. Also, there was limited time for meetings and focus groups, and both of these were scheduled events. As such, an exchange of ideas was sometimes forced, instead of being organic. With only 10 Girl Scouts, this study allows a glimpse into the informal STEM education world and the possibilities that it holds, however, it is limited in scope with this small group. The reflective journal is a collection of memories which may not accurately reflect the meaning of the community member during the event itself. Finally, generalizability is not possible with a study of this sort. Although these limitations are important to explain, using the AR methodology and engaging the scouts in an informal, authentic science experience, allowed for the scouts to explore science, technology, engineering, and mathematics in new ways that were supportive of traditional K-12 classroom settings.

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