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Integrating Place-Based STEM Education to Reach Underrepresented Populations in Rural United States: TRAILS 2.0

SESSION VI: Design Thinking and Practice

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Abstract

A NSF proposal, TRAILS 2.0, was funded for scale-up of the project called Teachers and Researchers Advancing Integrated Lessons in STEM (TRAILS). The new TRAILS 2.0 project will address the needs of diverse populations in rural school settings utilizing additional approaches including Place Based Education. TRAILS seeks to help underserved, underrepresented students living in rural America through an integrated STEM framework.

Introduction

Public schools in rural settings serve one-third of all students in America (Williams, 2010; U.S. Department of Education, 2010-2011). However, little attention is given to prepare these youth for careers in STEM fields and there is a lack in programs to improve rural science education (Avery, 2013). Furthermore, there are multiple barriers that exist for rural students who aspire to follow a STEM career pathway. These barriers include a) an absence of STEM role models (Fouad & Santana, 2017; National Academies, 2011), b) limited access to career-advisors with necessary STEM career expertise (Grimes, Arrastía-Chisholm; & Bright, 2019), c) insufficiencies in career preparation and interest; and d) limited availability to post-secondary education and lack of opportunities to learn STEM content within classes (Saw & Agger, 2021). The TRAILS 2.0 program was developed to help rural students overcome these challenges based on the ***situated learning theory*** to blend both physical and social elements of real-world learning within a community of practice to create authentic learning (Greeno, Collins, & Resnick, 1996; Brown, Collins, & Duguid, 1989; Lave, & Wenger, 1991; Putnam & Borko, 2000; NRC, 2014). TRAILS 2.0 has added a focus on **Place-based education (PBE**) (Semken, 2005) that provides a context for rural schoolteachers to leverage local and indigenous knowledge of history, nature, habitats, culture, and the economy as context for learning STEM (Avery & Kassam, 2011; Chinn, 2011). The current article will revisit the Kelley & Knowles (2016) framework. Authors will illustrate that while remaining true to the conceptual framework, new theories help TRAILS 2.0 researchers and teachers reach these special population of students. We will highlight these novel approaches in pedagogy and new research techniques to help reach new audiences and prepare students to pursue STEM careers. The authors will show how engineering technology education teachers using engineering design pedagogical approaches can also provide place-based learning and leverage local rural knowledge within a community of practice to reach students.

Literature Review

A quick review of the STEM education status reports indicates that students are falling behind their international peers (Hossain & G Robinson, 2012; President's Council of Advisors on Science and Technology [PCAST], 2010). Additionally, many countries are calling for the need for STEM workers in the 21st Century with a focus on a globalized economy (National Academies of Sciences, Engineering, and Medicine, 2016; OECD, 2011; TIMSS Advanced, 2015; National Research Council, 2011, 2015; NGSS Lead States, 2013). Moreover, there is increased concern to help prepare students from underrepresented populations and many of these students are disinterested in STEM careers and struggle to achieve success in STEM related content classes (Kricorian, Seu, Lopez, Ureta, & Equils, 2020). Often an overlooked and growing population in the United States is the underserved and underrepresented student population living in rural school settings. There are multiple barriers that exist for rural students who aspire to follow a STEM career pathway. These barriers include a) an absence of STEM role models (Fouad & Santana, 2017; National Academies, 2011), b) limited access to career-advisors with necessary STEM career expertise (Grimes, Arrastía-Chisholm; & Bright, 2019), c) insufficiencies in career preparation and interest; and d) limited availability to post-secondary education and lack of opportunities to learn STEM content within classes (Saw & Agger, 2021). Motivating rural school students to learn and apply STEM content is critical if these students are to aspire to pursue a STEM career. Additionally, it is vital for the economic success of any country within a globalized economy to properly educate all students and inspire them to join a new generation of STEM experts. This is especially true for underrepresented students living in rural settings who have often been left behind. This will require a new way of thinking and an innovative approach to integrated STEM education for this special population.

Although some suggest that students from rural communities can help fill the void in the STEM pipeline, there are many barriers to limit rural student's success, including limited educational resources, STEM teacher shortages, poverty, lack of school funding, and low parental awareness of STEM careers (Rogers & Sun, 2018). Barshay (2021) found 12% of rural and suburban students enter high school expresssing interests in STEM careers. However, rural students enter with lower math scores and as the math gap increases each year, their desire to pursue a career in math or science drops below 9 percent by 11th grade. Rural students lag their urban and suburban peers in 4 year college enrollment and then lag in majors in math and science, 13 percent compared with 17 percent of suburban students. Wells et al. (2023) find that rural students of color are more impoverished and experience higher barriers to accessing postsecondary education than white peers with American Indian and Alaska Native, 54% living in rural areas or small towns, having the lowest high school graduation and college enrollment rates of all groups.

Additionally, while rural students outperform urban students on the National Assessment of Educational Progress assessment (NAEP, 2009; 2011) and high school graduation rates, they lag in college enrollment (Avery, 2013; Schafft & Jackson, 2011). This problem is compounded because many rural students do not have exposure to diverse examples of STEM in practice and lack STEM role models. Therefore, students fail to envision STEM related career pathways (Avery, 2013).

Overview of TRAILS

The following article will share results from a 3-year (2016-2018) NSF funded integrated STEM project called: Teachers and Researchers Advancing Integrated Lessons in STEM (TRAILS) and share how researchers propose leveraging lessons learned from this project to reach new audiences, especially students from underserved and underrepresented populations within rural school settings. The authors will provide a rationale of how our national population migration is changing within rural school settings and how STEM educators must adapt to meet the STEM education needs of these often-overlooked group of students.

The TRAILS project was a three-year-long grant funded by the National Science Foundation (NSF). For three consecutive years, from 2016 until 2018, high school science and engineering teachers participated in a hands-on summer professional development (PD) workshop for two weeks for over 70 PD contact hours. During the professional development, teachers participated in an exemplary integrated STEM unit, *Designing Bugs and Innovative Technology (D-BAIT)*, where teachers learned how to integrate STEM disciplines in a biomimicry context just like high school students would experience in an integrated lesson. In this unit, teachers learned about aquatic insects, food webs, buoyancy, engineering design, CAD software, and 3D printing to create a biomimicry-inspired fishing lure, and prototypes were tested in a nearby pond. Teachers also collaborated during the second week of the professional development workshop to create their own integrated STEM units to be co-taught for the next school year. During this time, partnered teachers developed lessons, teacher and student classroom materials, and proof-of-concept prototypes in preparation for implementing their STEM units during the school year. The following school year, researchers, educators, and industry partners collaborated to provide a variety of STEM learning opportunities to support these teachers in unit plan implementation. 43 STEM teachers participated in the project, and 20 integrated STEM lessons were implemented in 47 STEM classrooms over three years (2016-2019 academic years). These twenty integrated STEM units included the one exemplar lesson, D-BAIT, developed by the researchers, and nineteen custom lessons developed by the researcher-teacher collaboration during the professional development workshop that are now accessible to anyone for free on the TRAILs website at www.purdue.edu\trails.

The TRAILS researchers learned a great deal from the participants of the TRAILS program within Indiana. Researchers learned that teachers benefit from engaging in active learning just like their students and doing so with their peers and experts from a community of practice to help teachers prepare to implement integrated STEM activities in their classrooms. Researchers learned that teachers benefit from engaging in shared practices taken from their own discipline (science inquiry for Biology and CAD and 3D printing for Engineering Technology Education teachers). TRAILS teachers engaged in these practices together, so each discipline learned skills and procedures outside their content area. The TRAILS researchers believe that these features of the TRAILS professional development had a positive impact on teachers and impacted their students positively, the collecting research results are evidence to back up these claims about the TRAILS program in Indiana.

Results from TRAILS

Teacher Self-Efficacy

TRAILS experimental group teachers participated in the summer professional development and implemented integrated STEM in their classrooms during the following school year. The teachers took the Teacher STEM (T-STEM) survey before PD (pretest), after PD (posttest), and after they instructed their students with integrated STEM lessons (delayed posttest). Comparison group teachers only took T-STEM surveys and did not participate in PD nor taught integrated STEM. Statistical analysis results from a Wilcoxon rank-sum test showed significant difference between experimental group ($N = 30$) and control group teachers ($N = 18$) in terms of self-efficacy increase from the pre- to posttest ($p = .048$, effect size = .29) and from the pre- to the delayed posttest ($p = .034$, effect size = .32) (Kelley et al., 2020).

Additionally, teacher self-efficacy and outcome expectancy were found to influence students' STEM attitudes, STEM career awareness, and STEM content knowledge directly and indirectly (Han, Kelley, & Knowles, 2021).

Student STEM Content Knowledge

Students increased STEM content knowledge from inquiry and design-based integrated STEM instruction as measured by *D-BAIT* STEM knowledge pre- and posttest. The results from the paired samples *t*-test revealed that the experimental group students' knowledge test score increases were statistically significant (t (712) = 13.167, $p < .001$, effect size = .493). When compared to the comparison group, experimental group students' knowledge test score increases from the pre- to posttest were statistically significantly higher (t (1020) = 6.342, $p < .001$).

Models of Integrated STEM Implementation

Three models of integrated STEM implementation emerged from the TRAILS classrooms: STEM content inclusion model, STEM content integration model, STEM content and practices integration model (Kelley, Knowles, Han, Trice, 2021). Analysis of the qualitative and quantitative data revealed the benefits of teacher collaboration (STEM content integration model, STEM content and practices integration model) in integrated STEM implementation. For example, STEM knowledge test score increases from pre- to posttest were significantly higher for the students taught by science and engineering teacher pairs than those taught by the single teachers (STEM content inclusion model) (Kelley, Knowles, Han, & Trice, 2021).

21st Century Skills Survey Instrument Development

TRAILS 1.0 researchers developed a new survey instrument that measures students' 21st century skills. 276 science and ETE students from 7 high schools participated in the survey. The subscales of this instrument include critical thinking, collaboration, communication, and creativity. The Cronbach's alpha reliabilities were Collaboration = .826; Communication = .749; Creativity = .751; and Critical Thinking = .876 (Kelley, Knowles, Han, & Sung, 2019). TRAILS 2.0 will use this new instrument to examine how integrated STEM lessons increase high school students' 21st century skills.

Lessons Learned from TRAILS 1.0

The lessons learned from the TRAILS approach to provide integrated STEM education to new audiences (in this case, rural populations with underserved and underrepresented populations) include the following:

1. Researching new audiences requires understanding what fundamentals of an existing program are necessary to retain. The fundamentals of the TRAILS conceptual framework will remain because these elements are necessary for integrating STEM content and sharing required practices.
2. New audiences require understanding and adjusting to the needs of those audience members. If TRAILS 2.0 will be successful for these new audiences, it will require listening to teachers and students to best understand their needs and their local place context.
3. Reaching new audiences often requires new contexts. Deeply rooted within place-based learning, local rural knowledge, culturally responsive pedagogy, and funds of knowledge are the concepts of learning all that you can about the people where you are teaching and locating ways to provide the most ideal contexts for them to learn best.

Next Steps

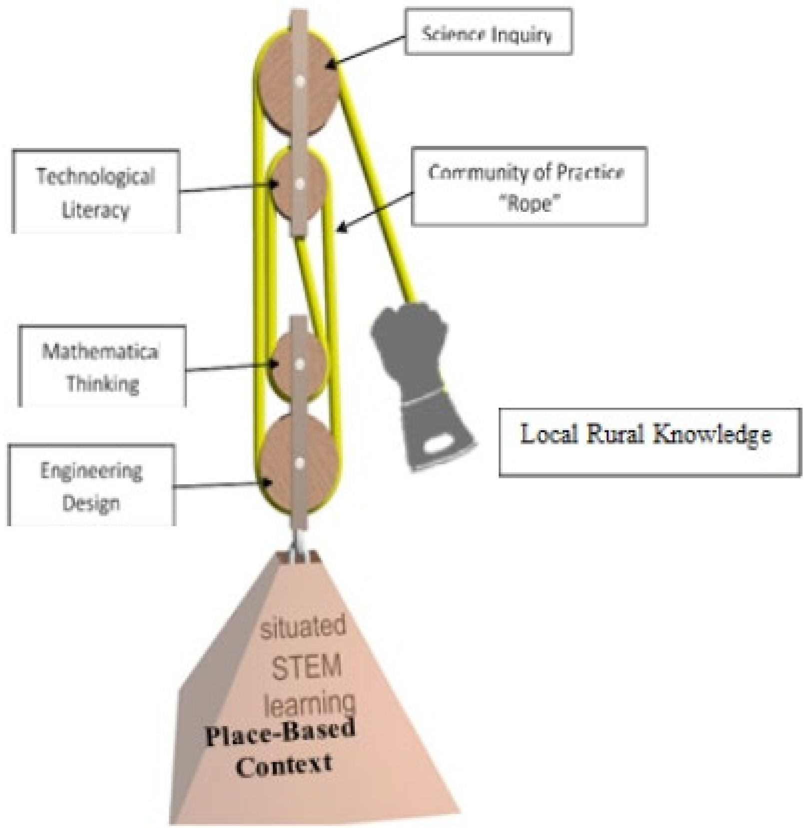
Although the TRAILS researchers believe that the program had positive effects on the participants based upon data collected which showed evidence of impact on teachers and students, questions remain how the program might be designed to impact all teachers and students. Specifically, the TRAILS team remains interested in how the program can reach new audiences; specifically, underrepresented, and underserved students living in rural school settings.

A recent phenomenon that has occurred in the United States as well as other regions of the world, is that people are more transient, relocating to other regions of the country and in some cases to another country. With this phenomenon in mind, the authors observed population data of various regions of Indiana. The researchers noticed pockets of diversity within small towns and rural settings. These examples include Frankfort, Seymour, and Logansport School Districts in Indiana which contain pockets of diversity within rural school locations. (***Frankfort,***

Indiana. Hispanic 53.2%, Multiracial 2.1%, Black/African American 0.7%, Hawaiian/Pacific Islander 0.2%, Asian 0.2%, Native American 0.1%, White 43.6%. ***Seymour, Indiana***. Hispanic 37.3%, Multiracial 2.9%, Asian 1.3%, Black/African American 1.1%, Native American 0.1%, Hawaiian/Pacific Islander 0.1%, White 57.3%. ***Logansport, Indiana.*** Hispanic 46.2%, Asian 2.9%, Black/African American 2.3%, White 45%. Data source: Indiana Department of Education). The TRAILS researchers were curious if this was true across the rest of the United States and studied the United States Department of Agriculture Economic Research Service Atlas of Rural and Small Town America (https://www.ers.usda.gov/data-products/atlas-of-rural-and-small-town-america), discovering there are multiple examples of throughout the country with diverse student populations within rural school settings. This interactive atlas allows researchers to view rural locations in the US and census data on population demographics within these settings. TRAILS researchers found rural settings with diverse populations of students as possible locations for implementing the TRAILS program. As a result, three regions of the country were located, and partnerships were formed in Maryland, Delaware, and Virginia along the Eastern Shore known as Delmarva. A second location was identified in Southeastern Colorado and Northern New Mexico. A third was in Hawaii. Collaborative partnerships were established with TRAILS researchers and faculty at University of Maryland Eastern Shore; Otero College, LaJunta, CO; and University of Hawaii.

TRAILS 2.0

As a new partnership was formed in these three regions of the US, the faculty worked to visit the existing TRAILS framework based upon the conceptual framework of Kelley and Knowles (Kelley & Knowles 2016). A new proposal was submitted to the National Science Foundation to reach new audiences with the TRAILS program. Within the proposal, the research team proposed modifying the Kelley & Knowles framework to include Local Rural Knowledge and Place-Based Education to better reach underrepresented students living in rural settings. These two theories provide strong approaches to meeting the needs of a learner living in small towns and rural locations and these two theories fit well within the Kelley and Knowles original framework. First, the theory of ***Local Rural Knowledge (LRK)*** introduced by Avery & Kassam (2011) "contextualizes rural children's local knowledge about science and engineering as the information and skills they have acquired in places outside of school" (p. 2). This framework views rural, place-based knowledge as positive assets, and it recognizes the importance of applying students' practical experiences in STEM learning. Rural students learn new STEM knowledge through active engagement and experience in their rural communities, but not solely through teacher's lecture. What the TRAILS researchers found within LRK was a strong connection with the theory of community of practice. The TRAILS program already saw success leveraging Community of Practice (CoP) for TRAILS 1.0. As a result, the leadership team saw immense potential in embracing a CoP with many local rural experts sharing their expertise during teacher professional development sessions and challenging teachers to locate local rural knowledge experts within the towns and villages where they teach. Advocates of LRK believe it can be an effective tool for STEM learning, as it allows rural students to see the applicability of STEM knowledge to their everyday experience (Avery, 2013; Avery & Kassam, 2011). Additionally, the TRAILS researchers aim to provide authentic integrated STEM learning opportunities to the new group of students. In achieving this end, the TRAILS researchers revisited the image of a block and tackle of four pulleys in Kelley & Knowles (2016), and examined how a ‘load’, “Situated STEM Learning,” can be contextualized as place-based learning. See **Figure 1**. below.



Place-Based Education (PBE)

For the past decade, The *Framework for K-12 Science Education,* Practices, Crosscutting Concepts, and Core Ideas (National Research Council 2012) has served as a foundation for developing the science standards of 24 states and the Next Generation Science Standards (NGSS), adopted by 20 states (https://ngss.nsta.org/about.aspx). By explicitly stating that the science “community and its culture exist in the larger social and economic context of their place and time and are influenced by events, needs, and norms from outside science” (p. 27) the Framework firmly situates science in historical and sociocultural contexts. In this light, rural learners of science would be more likely to develop identities as competent learners of science if their experiences are engaging, personally meaningful, and connected to the knowledge, experiences, and cultural identities they bring to the science classroom.

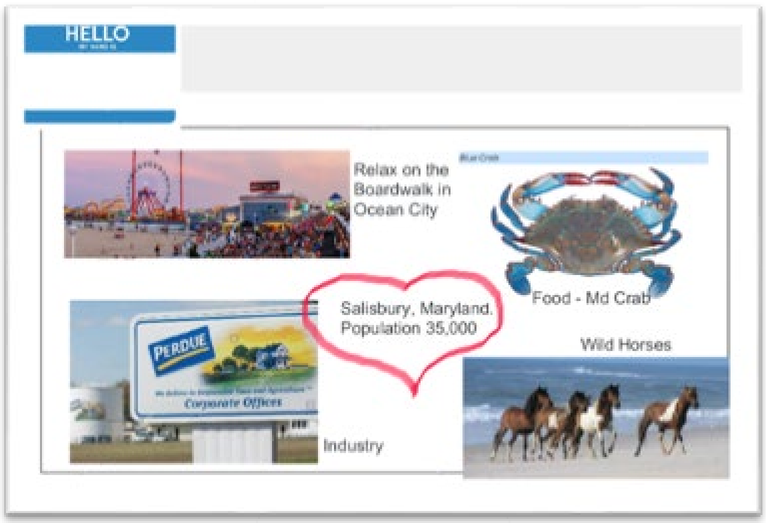
Hill et al. (2018) found middles school students valued informal and afterschol science related activities. Many rural towns rely on science-heavy fields including forestry and resource management that offer no cost and low-cost resources for rural STEM education. Inclusion of experiential and place-based activities and resources associated with agriculture, animal husbandry, 4-H, fishing, hunting could improve rural students’ science learning and engagement. Barshay (2023) finds it “curious that that rural students … don’t pursue studies that could lead to well-paying careers for themselves and a more productive economic future for their communities.

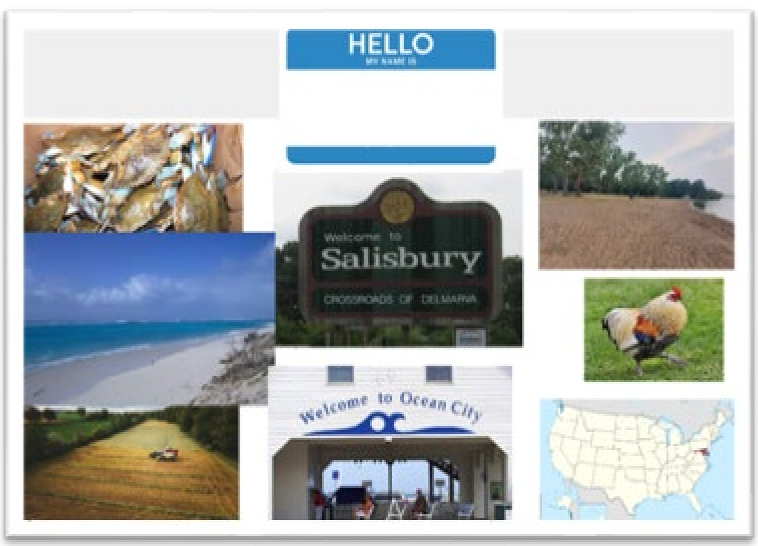
However, in addition to lower access to STEM courses, rural students, especially those of color including Native Alaskan, American Indian, Native Hawaiians and Pacific Islanders may find that teachers and administrators who are not from their communities and cultures view them through their own cultural lenses and stereotypical identities that influence the way they interact, evaluate, and form expectations. Rural students who live far from towns are more likely to live sustainable lifestyles unfamiliar to their teachers that rely on place based, culturally contextualized, intergenerational STEM knowledge addressing needs for food, water, shelter, health, and energy. This systems-oriented, situated body of knowledge is gained through hands-on, observational, interpersonal, and experiential learning processes that are meaningful and valuable at personal and community levels. These cultural funds of knowledge are resources that can be brought to STEM education if there are ways to intersect place-based, culturally shaped STEM knowledge and practices with that considered valuable by mainstream STEM education.

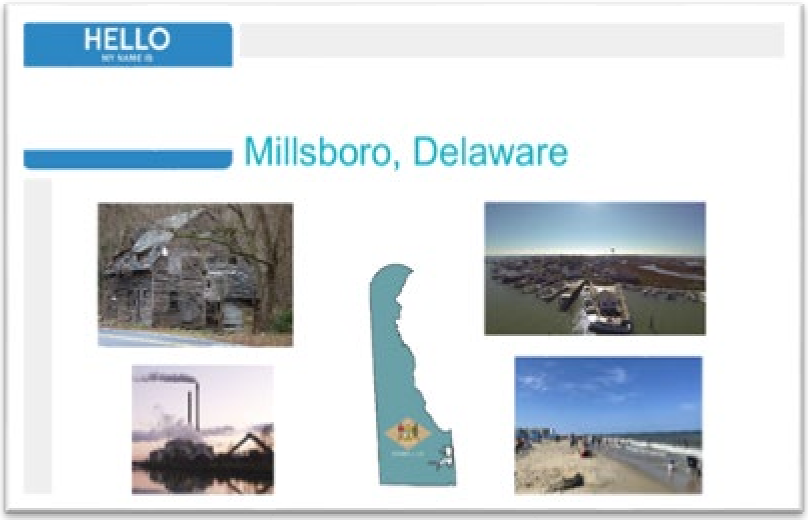
Modifying TRAILS Professional Development for Place-Based Approaches

TRAILS researchers require participating teachers to spend time thinking deeply about the place they teach and craft journal entries of their reflections before attending the summer PD. As Pauline Chinn (2011) indicates, PBE involves "asking teachers to reflect on a personal place could begin a transformation …. to thinking about it as experiential, real-world learning using a range of research methods" (p. 83). TRAILS researchers realize there is a great opportunity to continue to leverage a community of practice to assist in teaching science inquiry and engineering design as an essential pedagogy to integrated STEM while at the same time engaging local experts to gather local rural knowledge within the community (Katehi, Pearson, & Feder, 2009; NRC, 2011, Lewis, 2006). TRAILS also remains committed to teaching engineering design pedagogies with key elements such as an engineers' notebook (Kelley, 2011, 2014), decision matrix (Kelley, 2010b), and learning brainstorming approaches (Mentzer, Farrington, & Tennenhouse, 2015). These are fundamental approaches to integrated STEM and the TRAILS approach. Biomimicry is also integral for STEM learning when working with biology and engineering technology teachers since it naturally blends life sciences and engineering design to promote science-informed design solutions. Furthermore, careful **assessments of place** will provide researchers with understanding of key local rural knowledge, environmental concerns, and cultural contexts that can help the team know how to adapt the TRAILS lessons to meet the needs of rural students in various regions.

One adjustment that TRAILS researchers made to the professional development was to implement a *Place Postcard Activity*. The very first warm-up activity for TRAILS professional development requires teachers to create a 'postcard' providing images from their 'hometown'- the town where they teach. This activity encourages teachers to reflect on images which capture the environment, culture, and small-town life of the town where they teach. Teachers were allowed to make either a hard copy of the postcard or use a *Jamboard* slide to create a digital postcard. Next, teachers share their postcards with their peers at the professional development, allowing them to not just introduce themselves but also their local place and how this area is known. These postcards are qualitative research data for TRAILS researchers to better understand teacher's sense of place in their teaching context. Not only is this activity a great way to learn about the small towns represented at the PD but TRAILS researchers can utilize this data to help teachers create place-based lessons and craft place-based assessments. Below are a few examples of the postcard from the Cohort I (Delmarva Region along the eastern shore of Delaware, Maryland, and Virginia) and Cohort II (Southern Colorado, Northern New Mexico, and Western Kansas).







New Approaches Require New Assessments

The TRAILS program was successful in the state of Indiana. However, as the project has scaled up to include new audiences and reach different populations, this has required novel approaches not only with professional development activities but also new research methods. Adding place-based contexts to TRAILs lessons requires adjustments to curriculum and pedagogical approaches, and new research assessments. TRAILS researchers searched for assessment instruments that could be used to assess student engagement in place-based lessons and discovered a place attachment survey to assess student's attachment to a local place by Williams and Vaske (2003). The challenge in using a survey instrument with a specific localized place is that place attachment is very individualized. Therefore, TRAILS researchers conducted a pilot questionnaire to help determine what places students would identify as meaningful.

Place Attachment Instrument

The TRAILS project used Williams and Vaske's (2003) Place Attachment survey to reflect the contextual variance and modified it as suggested to suit the specific regional context of each cohort. Table 1 shows the initial survey developed by them.

Table 1. Initial Survey: 5 Likert Scale from 1 (strongly disagree) to 5 (strongly agree)

Place Identity
1. I feel (place name) is a part of me. 2. (Place name) is very special to me. 3. I identify strongly with (place name). 4. I am very attached to (place name). 5. Visiting (place name) says a lot about who I am. 6. (Place name) means a lot to me.
Place Dependence
1. (Place name) is the best place for what I like to do. 2. No other place can compare to (place name).

3. I get more satisfaction out of visiting (place name) than any other. 4. Doing what I do at (place name) is more important to me than doing it in any other place. 5. I wouldn't substitute any other area for doing the types of things I do at (place name). 6. The things I do at (place name) I would enjoy doing just as much as a similar site.

The pilot survey followed Williams and Vaske's (2003) elicitation survey, which was "to identify specific places the students were likely to visit through a series of six scenarios" (p.833). The results elicited four places that students are mostly like to visit. Following Williams and Vaske's (2003) method, the final survey was developed, which includes "a set of questions repeated four times, once for each of the four areas" (see table 2). The instrument has two subconstructs, place identity and place dependence, and each item asks the respondents to indicate how they feel about each statement using a 5-point Likert scale, 1 being "strongly disagree" to 5 being "strongly agree".

Table 2. Pilot Survey (Elicitation Survey)

	Williams & Vaske (2003, p.833)	TRAILS
Participants	25 undergraduate students at Colorado State University (CSU)	99 high school students from WICOMICO county
Scenarios for the Survey Questions	1. A Saturday afternoon in June 2. A day off in February 3. A fall weekend 4. A weekend trip in the summer 5. Spring break from classes 6. A general question asking about other places in Colorado that they like to visit.	1. A Saturday afternoon 2. A day off in February 3. A fall weekend 4. A weekend trip in the summer 5. Spring Break from school 6. A general question asking about other places they like to visit when they are stressed
Survey Questions	(Examples) Q1. (Scenario #1): "It is a beautiful Saturday afternoon in June, and you have a few hours before you have to go to work. You call a friend, and together, decide to spend some time outdoors. In the space below, list your top three choices of where you would go to spend your afternoon. Please be specific."	Q1. (Scenario #1): "It is a beautiful Saturday afternoon. You call a friend, and together, decide to spend some time outdoors. In the space below, list your top three choices of where you would go to spend your afternoon. Name local places, parks, beaches, trails, etc."
	Q2. (Scenario #2): The fall weekend scenario read: "Some out of town relatives are planning to visit you for a fall weekend. Since they've never been to Colorado, they are hoping that you will show them what it is about Colorado that you love so	Q2. (Scenario #2): "It is a cold day in February, and you have a day off. Instead of staying home, you would like to spend some time outdoors with your friends. In the space below, list your top three choices of where you would go to spend your

	much. Where would you take them? Again, please be specific."	day. Name local places, parks, beaches, trails, etc.
		Q3. (Scenario #3): "Some out of town relatives are planning to visit you for a fall weekend. Since they've never been to your place, they are hoping that you will show them what it is about your place that you love so much. Where would you take them? In the space below, list your top three choices of where you would go with them. Name local places, parks, beaches, trails, etc."
		Q4. (Scenario #4): "You are on summer vacation, and you would like to go somewhere with your family over the weekend. Your family is hoping that you will choose a place where you have never visited before and you would love to visit. Where would you like to go with them? In the space below, list your top three choices of where you would like to take them. Name local places, parks, beaches, trails, etc."
		Q5. (Scenario #5): "You have friends from other countries, planning to visit you during Spring Break. They are hoping that you will show them places in your region, meaningful to you. Where would you like to go with them? In the space below, list your top three choices of where you would take them within the Eastern Shore Region (Delaware, Maryland, Virginia). Name local places, parks, beaches, trails, etc."
Results - Four places that students mostly like to visit	1. Rocky Mountain National Park 2. The Poudre Wild and Scenic 3. Cameron Pass 4. The Horsetooth Recreation Area	1. Ocean City 2. Chesapeake Bay 3. Salisbury 4. Assateague Island Note. Places outside of the DELMARVA were excluded as outliers.

Table 3. Place Attachment Survey; 5-point Likert Scale from 1 (strongly disagree) to 5 (strongly agree)

Place Identity
I feel (place name #1) is a part of me. I feel (place name #2) is a part of me. I feel (place name #3) is a part of me. I feel (place name #4) is a part of me.
(Place name #1) is very special to me. (Place name #2) is very special to me. (Place name #3) is very special to me. (Place name #4) is very special to me.

Page Break

I identify strongly with (place name #1). I identify strongly with (place name #2). I identify strongly with (place name #3). I identify strongly with (place name #4).
I am very attached to (place name #1). I am very attached to (place name #2). I am very attached to (place name #3). I am very attached to (place name #4).
Visiting (place name #1) says a lot about who I am. Visiting (place name #2) says a lot about who I am. Visiting (place name #3) says a lot about who I am. Visiting (place name #4) says a lot about who I am.
(Place name #1) means a lot to me. (Place name #2) means a lot to me. (Place name #3) means a lot to me. (Place name #4) means a lot to me.
Place Dependence
(Place name #1) is the best place for what I like to do. (Place name #2) is the best place for what I like to do. (Place name #3) is the best place for what I like to do. (Place name #4) is the best place for what I like to do.
No other place can compare to (place name #1). No other place can compare to (place name #2). No other place can compare to (place name #3). No other place can compare to (place name #4).
I get more satisfaction out of visiting (place name #1) than any other. I get more satisfaction out of visiting (place name #2) than any other. I get more satisfaction out of visiting (place name #3) than any other. I get more satisfaction out of visiting (place name #4) than any other.
Doing what I do at (place name #1) is more important to me than doing it in any other place. Doing what I do at (place name #2) is more important to me than doing it in any other place.

	Doing what I do at (place name #3) is more important to me than doing it in any other place. Doing what I do at (place name #4) is more important to me than doing it in any other place.
	I wouldn’t substitute any other area for doing the types of things I do at (place name #1). I wouldn’t substitute any other area for doing the types of things I do at (place name #2). I wouldn’t substitute any other area for doing the types of things I do at (place name #3). I wouldn’t substitute any other area for doing the types of things I do at (place name #3).
	The things I do at (place name #1) I would enjoy doing just as much as a similar site. The things I do at (place name #2) I would enjoy doing just as much as a similar site. The things I do at (place name #3) I would enjoy doing just as much as a similar site. The things I do at (place name #4) I would enjoy doing just as much as a similar site.

Note. Place names for DELMARVA area: #1 – Ocean City; #2 - Chesapeake Bay; #3 - Salisbury; #4 - Assateague Island

Table 4. In-service Teachers created a place-based integrated STEM unit from TRAILS

Student-created Museum Model	**Key Components of Place Based Education (PBE)**	**Learning Objectives**
	PBE emphasizes: a. incorporating rural students’ local knowledge and experience in teaching (Smith, 2002). b. providing underrepresented students with opportunities to develop STEM knowledge and give access to a STEM career pathway (Semken, 2005). c. outdoor learning experiences that enhancing student engagement in science (Semken & Freeman, 2008).	Students will be able to: d. observe biological processes as a source of design inspiration. e. predict the outcome of changing inputs into a system. f. design and model a natural system using 3D printing. g. calculate a biodiversity index and correlate how that indicates the health of that ecosystem and identifies human impacts. h. interpret the River Continuum Concept text.

Standards addressed: Next Generation Science Standards (NGSS: HS-LS2, HS-ESS2, HS-ETS1), Standards for Technological and Engineering Literacy (STEL:-1N, 1R, 2T, 2X, 2Z, 4Q, 7X, 7Y, 7BB, 7CC, 7DD, TEC-1,6,8) (ITEEA, 2020).

New Audiences, New Approaches, New Research Methods

Taking an existing program to a new location and student and teacher populations requires modifying existing approaches and incorporating new ones. The TRAILS researchers kept the core elements of the program but modified some approaches to meet the needs of underserved and underrepresented rural students. For example, new TRAILS engineering design challenges include place-based local contexts that students can relate to and identify from their place. Additionally, teachers reflect on their sense of place and the relevance of place to the context of integrated STEM teaching (Woodhouse & Knapp, 2000; Semken, 2005). Teachers are also challenged to identify and engage members of their community of practice to leverage local rural knowledge around the STEM content and context (Peterson, Bornemann, Lydon, & West, 2015). Furthermore, the updated TRAILS professional development follows the six design concepts of *place-based education* that are: a) community as a classroom, b) learner-centered, c) inquiry-based, d) local to global, e) design thinking, and f) interdisciplinary (Vander Art, Liebtag, & McClennen, 2020). Most of these concepts were already rooted within the TRAILS program. One specific change for the TRAILS approach to reach new audience is to deliberately gather and use local and indigenous knowledge in rural school communities while providing students with localized contexts for science inquiry activities and engineering design problems.

New research approaches are also required to assess teacher and student learning of STEM education and impacts on teacher pedagogy. Community of practice was a key element to the original TRAILS program and foundational to a conceptual framework for integrated STEM (Kelley & Knowles, 2016). It remains a focus for taking TRAILS to new audiences. Fortunately, new instruments have been developed to assess community of practice. The Teacher COP Network Survey (Polizzi et al. 2021) is being used to assess the growth, development, and the impact on the teacher as educator and community leader from local, state, and national levels. This network survey is necessary to measure teachers' perceptions as agents of change.

Furthermore, TRAILS research includes new surveys to assess students' socio-emotional outcomes in STEM including: a) the STEM Semantics Survey (Knezek & Christensen, 2008) to assess students' attitude in STEM content; b) the STEM Career Interest Survey (STEM-CIS) (Kier, Blanchard, Osborne, & Albert,2014) to assess students' attitudes towards STEM careers; and c) the Place Attachment Instrument (Williams & Vaske, 2003) to assess attitudes towards the place-based context. To complement the surveys and gain additional insight into the impact of the integrated STEM units on student social-emotional learning, each student is required to respond to reflective prompts embedded in student digital engineers' notebooks at the end of each TRAILS unit. These prompts give students an opportunity to reflect on their experience learning in integrated STEM (science and engineering technology) teams, the place of integrated STEM in their school and community, and their thoughts of themselves as a learner with potential to pursue technology-rich STEM careers.

Data Collection and Preliminary Analysis

Teacher Data

A total of 41 teachers participated in the summer institutes with 17 teachers in Cohort I and 24 teachers in Cohort II ($N = 24$). See the tables below.

Table 5: Descriptive Statistics (*N*=41 teachers)

	Minimum	Maximum	Mean	Std. Deviation
Teaching years	0	26	11.41	7.345
Age	24	62	41.12	10.095

Table 6: Teacher Demographics (*N*=41 teachers)

Gender		Ethnicity					Total
Male	Female	White	Black	Hispanic	Asian	Other	
20 (48.8%)	21 (51.2%)	29 (70.7%)	4 (9.8%)	4 (9.8%)	2 (4.9%)	2 (4.9%)	41 (100%)

Student Data

361 students (ETE 164, Science 197) participated in the 2022-2023 Cohort I and engaged in the place-based integrated STEM lessons. Surveys were administered before and after the lesson implementation to assess the impact of place-based integrated STEM education on students' sense of place, 21st Century skills, STEM career interest, and STEM perception. Among the 361 participants, data from only the 200 students (ETE 112, Science 88) who had submitted the IRB consent form from their parents and assent from themselves were included for the data analysis.

Table 7: Demographics of all Participant Students

Gender		Grade				Ethnicity						
Male	Female	9th	10th	11th	12th	White	Black	Hispanic	Asian	Other	NA	Total
103 (51.5%)	97 (48.5%)	91 (45.5%)	49 (24.5%)	44 (22.0%)	35 (9.7%)	145 (40.2%)	140 (38.8%)	50 (13.9%)	4 (1.1%)	19 (5.3%)	3 (0.8%)	361 (100%)

Note: 361 participants participated in 2022-2023 Cohort I.

Table 8: Demographics of Student Sample for Analysis

Gender		Grade				Ethnicity						
Male	Female	9th	10th	11th	12th	White	Black	Hispanic	Asian	Other	NA	Total
103 (51.5%)	97 48.5%	91 (45.5%)	49 (24.5%)	44 (22.0%)	16 (8.0%)	90 (45.0%)	77 (38.5%)	21 (10.5%)	3 (1.5%)	9 (4.5%)	0 (0%)	200 (100%)

Note: The student sample consisted of 200 participants from the 2022-2023 Cohort I.

Data Analysis Methods

Paired Samples T-tests (IBM SPSS Statistics 26) were used to test for statistical significance. The deletion 'test-by-test' method was employed to handle missing values. Cases with missing values were excluded from the analysis, and each t-test used only cases with valid data for all pairs of tested variables. Therefore, the sample size is not constant across tests.

Data Analysis Results and Conclusions

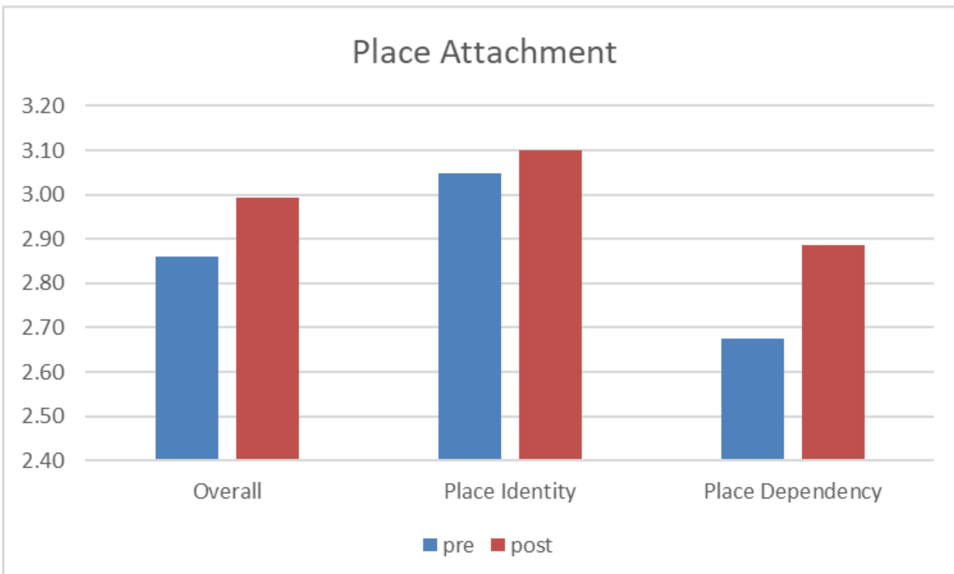
Teacher Survey Analysis Results

Overall CoP Network size significantly increased from pretest ($M = 5.925$, $SD = 3.430$) to posttest ($M = 9.300$, $SD = 6.140$) at a 95% confidence level (t (39) = 4.317, $p < 0.001$).

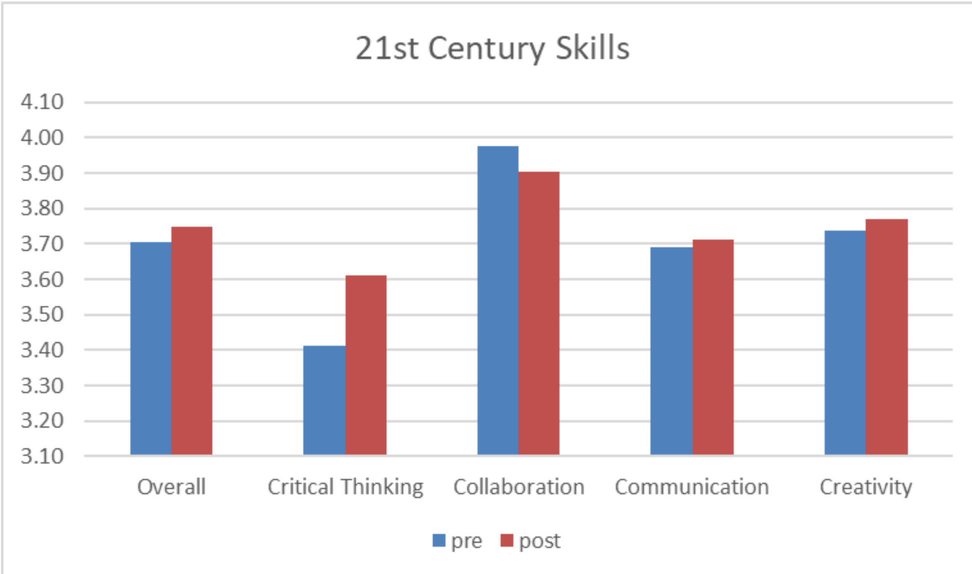
Additionally, overall Science Teaching Efficacy Belief (STEBI) and Engineering Teaching Efficacy Belief (ETEBI) increased from the pretest (*M* = 178.23, *SD* = 16.198) to the posttest (*M* = 188.30, *SD* = 17.715) at a 95% confidence level (*t* (39) = 3.038, *p* = 0.004).

Student Survey Analysis Results

Student Place Dependency increased significantly from pretest (*M* = 2.654, *SD* = 0.770) to posttest (*M* = 2.851, *SD* = 0.855) at a 95% confidence level (*t* (111) = 2.368, *p* = 0.020). Student Place Identity increased from pretest (*M* = 3.049, *SD* = 0.839) to posttest (*M* = 3.078, *SD* = 0.900), though this difference was not statistically significant at the 95% confidence level (*t* (111) = 0.379, *p* = 0.706).



Additionally, students' confidence in Critical Thinking, one of the four 21st Century skills, significantly increased from pretest (*M* = 3.369, *SD* = 0.889) to posttest (*M* = 3.604, *SD* = 0.914) at the 95% confidence level (*t* (96) = 3.037, *p* = 0.003).



Finally, overall students' STEM Career Interests increased from pretest ($M = 3.332$, $SD = 0.700$) to posttest ($M = 3.373$, $SD = 0.783$), but this difference was not statistically significant at the 95% confidence level (t (114) = 0.756, $p = 0.451$).

Conclusion

As expected, teachers showed a significant improvement in their self-efficacy in teaching science and engineering disciplines after participating in the summer PD institutes which focused on the local rural contexts for teaching STEM subjects. They also demonstrated an increase in their community of practice network size, indicating their ability to connect with individuals who share an interest in STEM education for rural high school students. Regarding the data analysis results for students, there was an increase in their place dependency after participating in the place-based integrated STEM project. Additionally, there was an improvement in their critical thinking skills.

Limitations

Student data showed nestedness, with students nested within each class. As a result, multilevel modeling was planned for the student data analysis. However, the data collected during one school year (COI) was not sufficient and did not meet the minimum requirements to proceed with multilevel modeling. Therefore, single-level analysis was employed, which may cause bias. After Cohort II, when more data is collected, multilevel modeling will be implemented to address this limitation.

Discussion

TRAILS researchers learned much from Cohort 1 and 2 participants in the TRAILS program as implemented so far. Teachers have benefited from engaging in active learning just like their students and doing so with their peers from their place-based context and experts from a community of practice. This assisted teachers in preparing integrated STEM lessons and activities in their classrooms. Results reveal that many features of the TRAILS professional development had a positive impact on teachers, especially in their confidence to teach science and engineering subjects. Results from Cohort 1 also show students were impacted positively, especially in their place dependency and identity, as well as critical thinking skills. Results so far provide evidence that the TRAILS program and approach can be successfully implemented in other locations to impact underserved and underrepresented students in rural regions of the United States.

References

Barnhardt, R. (2008). Creating a place for indigenous knowledge in education: The Alaska native knowledge network. In D. Greenwood & G. Smith (Eds.), *Place-based education in the global age : Local diversity* (pp. 113-134). Lawrence Erlbaum Associates.

Barshay, J. (July 12, 2021). PROOF POINTS: Rural American students shift away from math and science during high school, study finds. The Hechinger Report. Retrieved from https://hechingerreport.org/proof-points-rural-american-students-shift-away-from-math-and-science-during-high-school-study-finds/ Sept. 1, 2023.

Buck, G., Chinn, P. W. U., & Upadhyay. B. (2023). Science Education in Urban and Rural Contexts: Expanding on Conceptual Tools for Urban-Centric Research *in N. Lederman, D. Zeidler, J. Lederman (Eds.) Handbook of Research on Science Education, Volume 3, NY: Routledge.*

Chinn, P. W. U. (2023). Integrating Place, Indigenous and Western Science: Implications for Teacher Agency, Expertise, and Identity. In Pauline Chinn & Sharon Nelson-Barber (Forthcoming). Indigenous STEM Education: Perspectives from the Pacific and Asia, Vol. 1 and 2, Springer, Switzerland, AG.

Chinn, P. W.U., Kanahele-Mossman, H., Yuen-Apulu, V. L, M. & Cholymay, M. (2022). Honoring Diverse Knowledge: ‘A’ohe pau ka ‘ike i ka hālau ho’okahi | *AllKnowledge* Is *Not Learned in One School*, in M. M. Atwater (Ed.), *International Handbook of Research on Multicultural ScienceEducation*, Springer Nature Switzerland AG https://doi.org/10.1007/978-3-030-37743-4_5-1

Coleman, C., Chinn, P., Morrison, D. & Kaupp, L. (March 2019). How place-based science education strategies can support equity for students, teachers, and communities, STEM Teaching Tool Practice Brief 57, http://stemteachingtools.org/brief/57

Dubel, M., & Sobel, D. (2008). Place-based teacher education. In D. Greenwood & G. Smith (Eds.), *Place-based education in the global age : Local diversity* (pp. 309-344). Lawrence Erlbaum Associates.

Gruenewald, D. A., & Smith, G. A. (2008). Creating a movement to ground learning in place. In D. Greenwood & G. Smith (Eds.), *Place-based education in the global age : Local diversity* (pp. 345-358). Lawrence Erlbaum Associates.

Knapp, C. E. (2008). Place-based curricular and pedagogical models. In D. Greenwood & G. Smith (Eds.), *Place-based education in the global age : Local diversity* (pp. 5-28). Lawrence Erlbaum Associates.

National Research Council (2012). *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas*. Washington, DC: The National Academies Press. https://doi.org/10.17226/13165.

Tompkins, R. (2014). Overlooked opportunity: Students, educators, and education advocates contributing to community and economic development. In D. Greenwood & G. Smith (Eds.), *Place-based education in the global age : Local diversity* (pp. 173-196). Lawrence Erlbaum Associates.

Hossain, M., & G Robinson, M. (2012). How to motivate US students to pursue STEM (science, technology, engineering and mathematics) careers. *Online Submission*.

PCAST (President's Council of Advisors on Science and Technology). (2010). Prepare and inspire: K-12 education in STEM (science, technology, engineering and math) for America's future. Retrieved November 13, 2010, from http://www. whitehouse.gov/sites/default/files/microsites/ostp/pcast-stemed-report.pdf

Wells, R. S., Chen, L., Bettencourt, G. M. & Haas, S. (2023). Reconsidering rural-nonrural college enrollment gaps: The role of socioeconomic status in geographies of opportunity. Res High Educ. 2023 May 20 : 1–24. doi: 10.1007/s11162-023-09737-8 [Epub ahead of print]

Williams, D. R., & Vaske, J. J. (2003). The measurement of place attachment: Validity and generalizability of a psychometric approach. *Forest science*, *49*(6), 830-840.