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Board 181: Using an Integrated STEM Education Approach with Place-based Learning in a Community of Practice to Enhance Underrepresented Rural Student Learning

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Using an integrated STEM education approach with place-based learning in a community of practice to enhance underrepresented rural student learning (Work in Progress)

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Abstract

TRAILS is an integrated STEM education program designed to partner secondary teachers in engineering technology education with science teachers to implement integrated STEM curriculum. This year, an NSF scale-up grant was funded to continue research and implementation of the TRAILS project, TRAILS 2.0. The continuation of this work is now expanded to include a collaboration of partners. The TRAILS 2.0 project will address the needs of diverse populations in rural school settings. TRAILS seeks to impact underserved, underrepresented students living in rural America. Public schools in rural settings serve one-third of all students in the United States [1], [2]. Often little attention is given to prepare these youth for careers in STEM education and a lack in programs to improve rural science education remains [3]. Furthermore, multiple barriers exist for rural students who aspire to pursue a STEM career. The TRAILS 2.0 program is designed 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 foster authentic learning [4], [5], [6], [7]. TRAILS 2.0 adds a focus on *Place-based education (PBE)* [8] that utilizes a framework for rural teachers to leverage local and indigenous knowledge of history, nature, habitats, culture, and the economy as context for learning STEM content [9], [10]. While remaining true to the integrated STEM conceptual framework foundational to TRAILS 1.0 [11], new theories assist TRAILS 2.0 researchers and teachers to reach these special populations of students. The paper will highlight new approaches both in pedagogy and research techniques to impact new audiences and prepare underserved students for pursuing STEM careers. The authors will illustrate how engineering technology education teachers using engineering design pedagogical approaches can also provide place-based learning by leveraging local rural knowledge within a community of practice to engage students. Preliminary findings on this new cohort of teachers and students is presented from this first year of TRAILS 2.0 implementation in this Work in Progress paper.

There is increased concern to prepare students for STEM careers from underrepresented populations while conversely many of these students are uninterested in STEM fields and struggle academically in STEM related content classes [12], [13]. The underserved and underrepresented student population living in rural school settings is often an overlooked and growing population in the United States. Multiple barriers exist for rural students who aspire to follow a STEM career pathway. Motivating rural school students to learn and apply STEM content is critical if these students are to aspire to a STEM career. A new approach to integrated STEM education is key for this often-neglected population to find future success.

The following highlights results from a 3-year (2016-2018) National Science Foundation (NSF) funded integrated STEM project named TRAILS, and how researchers propose leveraging lessons learned from this grant to reach new audiences, especially students from underserved and underrepresented populations in rural school settings. A new and expanded NSF grant funded project, TRAILS 2.0, is designed to help rural students overcome these challenges based on situated learning theory**,** blending physical and social elements of real-world settings within a community of practice to cultivate authentic learning [4], [5], [6], [7], [14]. TRAILS 2.0 also integrates Place-Based Education (PBE) [8] by incorporating a framework for rural teachers to leverage local and indigenous history, nature, habitats, culture, and economy as a meaningful context for learning STEM subjects [9], [10]. TRAILS 2.0 is currently being implemented in the first academic year with cohort 1. The 3-year project will include 3 cohorts of teachers and students in 3 different locations (2022-2025).

TRAILS 1.0 was a three-year-long grant funded project. 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 PD, teachers participated in an exemplary integrated STEM unit, where teachers learned how to integrate STEM disciplines using a biomimicry context with engineering design as high school students would experience in an integrated lesson. Teachers also collaborated during the second week of the PD to create their own integrated STEM units co-taught the next 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. A total of 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).

TRAILS researchers learned much from the participants of the TRAILS 1.0 program within a midwestern state. Teachers benefited from engaging in active learning as their students would. However, these teachers also interacted with their peers and experts from a community of practice to assist them in implementing integrated STEM lessons in the classroom. Researchers learned that teachers benefit from engaging in shared practices from their own discipline. In this context, biology teachers used science inquiry, and engineering technology education (ETE) teachers used engineering design and 3D printing. TRAILS teachers collaborated in these practices together, so each discipline learned skills and procedures outside their content area. These features of the TRAILS PD seemed to positively impact teachers and their students. The research results affirm these claims about the TRAILS program especially regarding teacher self-efficacy, STEM content knowledge, models of integrated STEM implementation, and 21st century skill development. For example, science teachers significantly increased in teacher self-efficacy between the pretest before PD and delayed posttest scores after TRAILS PD and STEM lesson implementation (*p* = .001, effect size = .95, n=35) in comparison to a control group [15]. Furthermore, the community of practice participating in the PD seemed to significantly increase teachers' awareness of STEM careers in comparison to the control group (p = 0.001, effect size = 0.3, n = 21), especially among science teachers which showed a large effect size though they were a small sample size [16].

Although TRAILS 1.0 had positive effects on the participants based upon data showing impact on teachers and students, questions remain how this integrated STEM education approach might be more effectively designed and implemented to impact all teachers and students. Specifically, the TRAILS team is interested in how the program can reach new audiences, particularly underrepresented and underserved students in rural school settings. As a new partnership was formed in three rural regions, researchers and faculty reworked the existing TRAILS approach based upon the conceptual framework of Kelley & Knowles [11]. The new scaled-up project, TRAILS 2.0, uses a modified version of the Kelley & Knowles' framework [11] to include Local Rural Knowledge and Place-Based Education to enhance learning for underrepresented students living in rural settings. These two theories provide strong methodologies for meeting the needs of students living in small communities and rural locations.

First, the theory of Local Rural Knowledge (LRK) introduced by Avery & Kassam [9], aims to "contextualize 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, recognizing 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 and not solely through teaching in the classroom. TRAILS researchers found within LRK a strong connection with the Community of Practice (CoP). The TRAILS program already has shown success in leveraging a CoP in TRAILS 1.0. Further embracing a CoP with many local rural experts could enhance STEM learning. Local experts share their expertise during teacher PD sessions and challenge teachers to locate other LRK experts within the communities 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 [3], [9].

Second, Place-Based Education (PBE) reveals how situated learning theory can manifest in STEM classrooms. PBE grounds learning in a specific place where students are personally attached and live within the context [8], [14]. Many underrepresented students encounter disconnects between formal instruction and their home experiences as the content often used in classrooms does not reflect their community-based experiences. PBE addresses this challenge as it seeks to overcome this dissonance by leveraging learning from local surroundings [14]. In PBE, students are provided opportunities to explore local environments, phenomena, history, and economy in place. Teachers in rural school settings can use these place-based elements to create a meaningful STEM learning context for underserved populations [9], [10], [8]. The impact of implementing PBE in STEM activities can be powerful. Unique meanings and personal attachments are embedded in place among individuals and making use of place-based elements in STEM may allow underrepresented students to have a sense of connection, becoming more engaged in STEM learning [17].

TRAILS requires 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 Chinn [10] 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 realized 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 for gathering LRK within the community [18], [19], [21]. Careful assessments of place will provide the TRAILS team with understanding of key local rural knowledge, environmental concerns, and cultural contexts that will help in adapting TRAILS lessons to meet the needs of rural students in the three regions.

Though TRAILS 1.0 was successful in many respects, as this approach is scaled up to include new audiences and reach populations, this requires new approaches not only with PD activities but also new research methods. Adding place-based contexts to TRAILS lessons require adjustments to curriculum and pedagogical approaches as well as new research assessments. TRAILS researchers began to search for assessment instruments that could be used to assess student engagement in place-based lessons. TRAILS 2.0 utilizes a place attachment survey to assess student’s attachment to a local place by Williams and Vaske [21]. The challenge in using a survey instrument with a specific localized place is that place attachment is very individualized. This required TRAILS researchers to pilot a questionnaire to help determine what local places students would identify as meaningful.

The pilot survey followed Williams and Vaske’s [21] 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 mostly like to visit in the Delaware, Maryland, & Virginia peninsula region. These locations that students identified included: Ocean City, Chesapeake Bay. Salisbury, and Assateague Island. Not surprisingly, all these locations have strong ties with the region’s history, culture, industry, and natural environment unique to the area. Following Williams and Vaske’s [21] method, TRAILS researchers developed the final survey known as the Place Attachment Inventory (PAI), which includes “a set of questions repeated four times, once for each of the four areas.” 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”.

The student data collected during the Fall semester of 2022 provided a small sample size (n = 25) since many teachers plan to implement TRAILS in the Spring of 2023. TRAILS teachers are currently or yet to implement TRAILS lessons and the results have not shown statistical significance probably due to small sample sizes. However, some interesting results are developing as of this time in early 2023. For the Place Attachment Inventory, the following results were found, with the demographics in Table 1 (n=26):

- Overall Student Place Attachment increased from pre to posttest ($t(25) = 1.010$, $p = 0.322$).
- Student Identity increased from pre to posttest ($t(25) = 0.338$, $p = 0.738$).
- Student place dependence increased from pre to posttest ($t(25) = 1.518$, $p = 0.141$).
- All increases were not statistically significant at the 95% confidence level ($p > 0.05$).

Table 1: Place Attachment Inventory Student Demographics

	Gender		Grade		Ethnicity				
Total	Male	Female	10th	11th	White	Black	Hispanic	Asian	NA
26 (100%)	18 (69.2%)	8 (30.8%)	15 (57.7%)	11 (42.3%)	13 (50%)	2 (7.7%)	1 (3.85%)	1 (3.85%)	9 (34.6%)

The results at present appear to indicate increases in student place attachment as they more strongly identify with their local community. More data is currently being collected at several schools.

While TRAILS 1.0 strongly incorporated a Community of Practice (CoP), the impact of the CoP in the PD and lesson implementation was not specifically measured. The TRAILS 2.0 program will leverage a community of practice (CoP) that includes experts from advanced manufacturing, biological sciences, and 3D scanning experts who will provide examples of how 3D printing is changing their practices, providing a link between science and technology development. Engaging a community of practice moves beyond sharing stories but engaging experts and novices in learning and knowledge discovery [22] and embracing teaching shared practices captured in NGSS [23]. Since the TRAILS 1.0 community of practice members significantly impacted teachers' awareness of STEM careers [16], researchers would also like to measure impacts on teachers' community of practice (CoP) network.

To measure changes in the TRAILS teachers' CoP network, the Teacher CoP Network Survey [24] is being used to assess teachers before and after the week of PD, as well as later in the school year after lesson implementation. Polizzi, et al. [24] note that "Teacher CoP has been described as a group of educational stakeholders who interact around domains of knowledge (i.e., pedagogical, disciplinary) and practices" (p. 3). The Teacher CoP Network Survey measures the establishment and growth of teachers' community of practice network size, energizing contacts, frequency of interaction, network density, network bridging, and network reach at the school, district, state, and national/international community level, using 18 statements. This instrument uses social network analysis (SNA) with visual network scales (VNS) to visualize and quantify characteristics of the CoP and then relates this to the constructs of self-efficacy and identity [24]. Preliminary results measured before and after the PD are shown below from our initial group of TRAILS 2.0 teachers (COP) Network Survey ($n = 7$).

- Overall CoP Network size increased at the 95% confidence level ($p < 0.05$).
- CoP Network size at the national/international level increased at the 95% confidence level ($p < 0.05$)
- CoP Network sizes at the school level, district level, and state level increased at the 90% confidence level ($p < 0.1$)
- CoP Network Density at the National/International level increased at the 90% confidence level ($p < 0.1$)

CoP was a key element in the TRAILS 1.0 program and foundational to a conceptual framework for integrated STEM [11]. CoP remains an important focus for taking TRAILS to new audiences. Taking an existing program to new locations and new students and teacher populations requires modifying existing approaches as well as incorporating new methodologies. Teachers are challenged to identify and engage members of their CoP to leverage local rural knowledge around the STEM content and context [25]. New research approaches also require methods and instruments to assess teacher and student learning of STEM education content, interest, and impacts on teacher pedagogy.

TRAILS 2.0 research includes new surveys to help assess students' socio-emotional outcomes in STEM including: the STEM Semantics Survey [26] to assess students' attitude in STEM content, and the STEM Career Interest Survey (STEM-CIS) [27] to assess students' attitudes towards STEM careers. 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 content in their school and community, and their thoughts of themselves as a learner with potential to pursue technology-rich STEM careers. Currently TRAILS researchers are collecting this data on students and teachers during the 2022-2023 academic year which will be shared in the future.

Lessons learned from the expanded TRAILS approach to implement integrated STEM education in 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. Fundamentals of the TRAILS 1.0 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 understanding their place-based 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 concepts of learning that can be leveraged to enhance teaching. These learning approaches provide ways to locate the most ideal contexts for students to effectively learn and make connections between STEM knowledge and their personal experience.
4. With new pedagogical and learning approaches in new rural underrepresented contexts, new assessments and instruments are required to collect data and measure possible changes and impacts on teachers and students in these local integrated STEM contexts.

This is the first school year (2022-2023) of TRAILS 2.0 implementation and data collection. Though the small sample of results appears promising, more data is currently being collected for the remainder of this school year for cohort 1. Cohort 2 teacher PD will be held in June of 2023 in the second location with subsequent implementation during the 2023-2024 school year. Then cohort 3 PD will be held in June of 2024 in the third location with implementation and data collection concluding at the end of the third cohort in June 2025.

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