# BOARD # 233: Culturally Responsive Energy Engineering Education in Rural/Reservatio Elementary Schools - NSF RET Site at Montana State University

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Rebekah Hammack is an Assistant Professor of K-8 Science Education at Purdue University. She served as an Albert Einstein Distinguished Educator Fellow in the Division of Research on Learning in Formal and Informal Learning. Dr. Hammack's research focuses on the connection of local contexts to STEM interest and identity development in youth, particularly rural youth in elementary and middle grades, as well as how elementary teachers develop teaching efficacy and identity as STEM educators. Through her research, Dr. Hammack aims to advance understanding of how to enhance STEM education in rural schools and communities, providing opportunities to meet the unique needs of rural students.

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Nick Lux is a Professor of Curriculum and Instruction in MSU's Department of Education and is an affiliate of the Montana Engineering Education Research Center. He has worked in the fields of K-12 and higher education for almost 25 years, and currently teaches in the teacher education program and specializes in educational technology. His teaching and research interests include technology integration in K-12 STEM teaching and learning, and in particular, STEM education and STEM identity formation.

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## Motivation

With population density ranking 48th of 50 states, Montana is remote, boasting some of the most geographically isolated communities in the nation. Along with mountain ranges, extreme seasonal conditions create barriers between communities leading Montana to be more accurately described as a frontier rather than rural [1]. Owing to its remoteness and unique cultural landscape, approximately 6% of Montana land (over 5.5 million acres) includes 7 sovereign American Indian Reservations, home to 13 Tribes, and all with substantial energy resources – both traditional and renewable. Overall, Montana has nearly one-third of the US coal reserves, is the fifth-largest state producer of hydroelectric power, refines over 200,000 barrels of crude oil per day, hosts one of the largest underground natural gas storage sites in the world, and has enormous renewable energy production and potential, making energy a leading industry [2].

These existing and emerging energy industries necessitate a robust energy and engineering workforce in our EPSCoR designated region; however, this is a challenge with Montana's rural nature. Montana has the highest percentage of rural/frontier schools of any other US state [3]. In nearly every community of Montana, the need for high quality elementary teachers exists; however, only 3% of elementary teachers have college degrees in science or mathematics, and only 3% of elementary teachers have taken an engineering course in college [4]. Among elementary teachers, more than half (51%) say they are not adequately prepared to teach engineering, with only 14% feeling at least fairly-well prepared and only about a quarter (26%) feel prepared to encourage students' interest in science and/or engineering. Fewer than a third of all K-12 science teachers have attended professional development (PD) to deepen their understanding of how engineering is done [4].

The need to equip Montana's elementary teachers with engineering empowerment and knowledge is high, especially considering that early intervention in students' STEM identity formation is key. Alarmingly, girls start to lose interest in engineering around the age of twelve [5] and students who do not form an engineering identity at an early age do not pursue engineering careers [6]. Further, stereotypes of STEM professionals in the media have been found to negatively influence students' perceptions of STEM fields [7]. Social, cultural and gender norms, and the absence of role models and mentors can also challenge engineering identity formation, especially in young female and underrepresented minority students, e.g., rural and/or American Indian. Findings from these previous studies underscore the importance of enculturing self-efficacy in STEM teaching by providing elementary teachers research experiences and PD to both teach and encourage students to appreciate, understand, and perhaps, identify with engineering.

To empower elementary school teachers for a strong and diverse future energy engineering workforce in Montana, we aimed to recruit pre- and in-service elementary teachers (grades K-5) from Montana's rural and reservation communities to participate in an NSF RET Site housed

within the Montana Engineering Education Research Center (MEERC) at Montana State University (MSU) in Bozeman, MT. The MEERC RET Site leveraged both existing and new partnerships formed throughout the three-year project to provide teachers with research experiences in the wide array of energy-related research at MSU. Through this experience, teachers created culturally inclusive curriculum for their rural classrooms to help foster early student STEM identity formation.

The MEERC RET Site's intellectual foci of ***energy and engineering*** are also major areas of focus for the Montana University System's Science and Technology Plan as well as one of MSU's Research Grand Challenges. Energy is a key part of the Next Generation Science Standards (NGSS) cross cutting concept (CCC) of "Energy and Matter". Montana adopted NGSS-like standards that contain all the NGSS CCCs and most of the same performance expectations (standards) as NGSS. CCCs receive the least amount of attention of the NGSS dimensions and a lack of focus on CCCs can perpetuate misconceptions in children [8]. CCCs have also been reported as a potential "bridge" for the integration of science and engineering in K-12 classrooms [8]. The foci of energy and engineering also lend themselves to authentic research experiences and high-impact teacher PD activities at MSU.

**MEERC RET Site Description**

Three overarching goals of the MEERC RET Site: **Culturally Inclusive Energy and Engineering Education for Rural and Reservation Elementary Schools** include: (1) promoting inclusive engineering identity formation among diverse rural and reservation students, by (2) increasing elementary teacher self-efficacy in culturally inclusive energy and engineering education via (3) enhancing a collaborative ecosystem among regional elementary schools, industry, national laboratories, non-profit organizations and academia that supports teachers' development and implementation of engineering curricula that focuses on energy and diversifying the future engineering workforce. To achieve these goals, the three-year MEERC RET Site facilitated an engaging, holistic and integrated six-week summer experience for 31 in-service and pre-service elementary teachers, which (1) provided authentic energy-related research experiences within engineering laboratories and with appropriate scaffolding and connections to elementary settings, coupled with (2) customized, guided and reflective tours of Montana energy industry facilities and nearby Indigenous cultural venues, all while (3) fostering development, integration and sharing of unique and high-impact energy-related engineering curricula in diverse elementary classrooms and beyond.

Following orientations, training, and semi-structured two-way knowledge exchange opportunities, Site participants engaged in hands-on energy-related research experiences, working with engineering faculty and students and contributing directly to funded research projects such as building energy systems, biomass energy conversions, fluid flow processes, materials for energy conversion technologies, and sustainable transportation systems. In addition, cohorts engaged in customized and guided field trips and group outdoor recreational activities, providing powerful community-building experiences to enhance teacher PD.

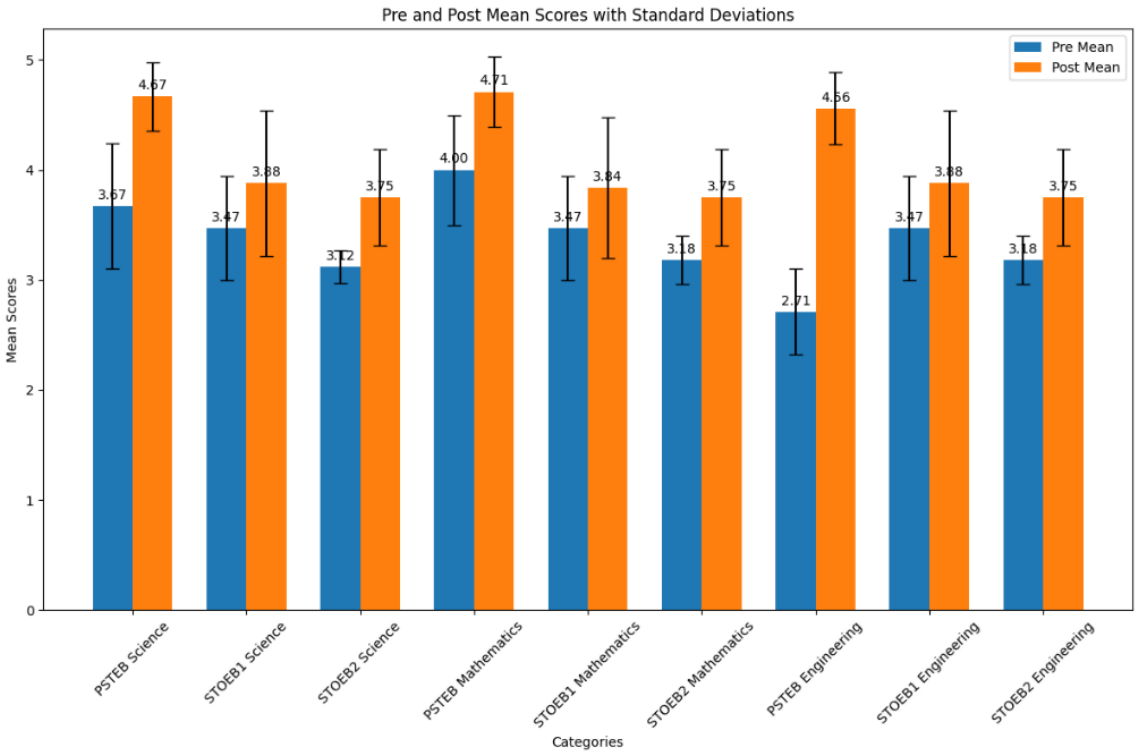
Throughout the six-weeks, the MEERC RET Site Project Team worked with teachers on essential understandings from Montana's Constitutional Article, Indian Education for All (IEFA), which aims to recognize and preserve the unique cultural heritages of American Indians [9]. The Site Project Team continues to support participating teachers, and their integration and assessment of IEFA-aligned engineering classroom activities developed through their Site experiences. Project products are shared widely through established venues at MSU and elsewhere, including educational content used in pre-service teacher education courses.

**MEERC RET Site Results**

After applying for the program, thirty-one (31) excellent elementary teachers (8 pre-service and 23 in-service) participated in the first three years of the NSF MEERC RET Site at MSU. These elementary teachers represented diverse rural and reservation communities from across Montana, including single room K-8 schools, and representing each of the seven American Indian reservations. Each year, applications far-exceeded participant positions; averaging ~22 applications per year, with 11 teachers participating during year one, 12 year two, and 8 in year three, with no repeating participants.

Based on the first cohort of the MEERC RET Site, Montana's 2020 teacher of the year, Dr. Linda Rost, published their Texas Tech PhD dissertation entitled, "*"I Didn't Know My Ancestors Were Engineers": Describing Elementary Science Teachers' Disposition for Indigenous Science and Engineering within an Energy Focused Summer RET Program through Holographic Epistemology"*, as well as an associated research manuscript published in *Science and Children*: "The Tatanka Teacher: Developing Dispositions for Indigenous Science Knowledge to Design and Assess Lesson Plans in Elementary Environmental Science" [10, 11]. Separately, supported by the comprehensive quantitative and qualitative data from year one, the MEERC RET team published a research manuscript published in the Journal of STEM Outreach [12]. The MEERC RET was also publicized on several media outlets, including Montana's electric utility, Northwestern Energy's quarterly publication, "Bright Magazine", which featured an article on the MEERC RET teachers' tour of the 100-year-old Madison Dam hydroelectric facility [13]. Additionally, MSU's News Service published annual stories shared throughout Montana [14-16]. The MEERC RET results were presented by the PI, Co-PIs and participating teachers at various professional Conference presentations, and in collaboration with the ASEE, the MEERC RET Site team recorded a webinar published on YouTube [17].

The Teacher Efficacy and Attitudes Toward STEM (T-STEM) survey, developed by the Friday Institute, was administered at the beginning (pre) and near the end (post) of each of the three MEERC RET Site summers. The bar chart below illustrates the combined pre and post mean scores for Personal Science Teaching Efficacy Beliefs (PSTEB), Science Teaching Outcome Expectancy Beliefs (STOEB) across three curricular areas: science, mathematics, and engineering for the three years, with error bars representing the standard deviations. The data shows significant improvements in all categories from pre-to-post scores for each year, indicating the positive impact of the MEERC RET Site on the participating teachers' self-efficacy and outcome expectancy beliefs, with the largest effect size in engineering.




Participant focus group discussions highlighted the positive impact of the MEERC RET Site on teachers' professional development, classroom practices, and personal growth. For example, one participant stated, "*the experience of being in a lab as a classroom teacher is really critical to teaching...it's refreshing, and it reinvigorates me for the upcoming year and makes me feel how I know what I'm about to teach is more authentic.*" The Site participants reported that the Site provided them with valuable resources, fostered strong relationships, and demonstrated effective ways to integrate engineering and IEFA into the elementary curriculum. For example, one stated, "*The IEFA experiences that we had were really valuable, too, because we're all required to teach IEFA and we want to do it in meaningful ways, and we want to do it well.*" Participants also exhibited substantial increases in comfort levels for designing and teaching engineering lessons and knowledge of STEM careers and resources. With one stating, "*We always know that there are these resources but knowing is one thing, but actually going and doing them is a different thing.*" And another, "*I can go back and tell my students, look at all these different engineering positions... So for me to be like, you are an engineer, and I was able to experience all of these amazing things with a bio-chemist or a bio-engineer or a civil engineer, or, you know, a quantum physicist.*" Finally, participants expressed unanimous desire for continued involvement and recommended the NSF MEERC RET Site to others. One participant summed up their personal and professional growth afforded through the experience as, "*I think another huge rewarding part for me is actually seeing myself in a science or engineering possible career field. I think for so long, I just had pushed it away because I just wasn't into that type of stuff. And now it's not intimidating. And I'm confident going into my new classroom and being able to teach that.*" This sense of confidence and competence (self-efficacy) in teaching engineering is reflected in both quantitative and other qualitative data and is testimony to the success of the MEERC RET Site.

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