Restoring Water, Culture, and Relationships: Using a Community Based Participatory Research Methodology for Engineering Education

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Dr. Jillian Cadwell's research incorporates an interdisciplinary study of ecology and fluid mechanics with a focus on the role of contaminant transport in the ecological health of aquatic environments. Additionally, Dr. Cadwell develops culturally relevant, place-based STEM curriculum for 3rd-6th grade students. Dr. Cadwell currently consults on a $1.2 million NSF grant that she procured in partnership with the University of Idaho faculty in Curriculum and Instruction, UI Extension, and two local Native American Indian Tribes: the Coeur d'Alene (CdAT) and Spokane (ST) tribes. The grant, ITEST, Strategies Project—Back to the Earth (BTTE), is addressing a national call to increase the STEM workforce pipeline by supporting and improving the STEM educational experiences for Native American students. Dr. Cadwell is a member of the grant leadership team with expertise in STEM content, curriculum development, and technology education. The team is using an interdisciplinary framework to reach under-served populations. The BTTE project delivers a culturally relevant and content rich STEM summer and after-school program for students in grades four through six on the Coeur d'Alene and Spokane reservations. Dr. Cadwell coordinates and oversees the development and implementation of the engineering activities for the program curriculum. - See more at: http://www.asee.org/public/conferences/20/papers/7302/view#sthash.eUFrQJ3A.dpuf

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Introduction

Despite current educational reform, efforts to improve Science, Technology, Engineering, and Math (STEM) education have failed to affect the number of STEM degrees awarded to American Indian students[1-2]. In an effort to increase the number of American Indians in technical and leadership positions, local tribal communities are pursuing opportunities for their youth to connect with STEM education that is relevant to their community and honors the Tribe's values. Community engagement and support for education is a recommended approach to inspire and increase academic achievement in American Indian students[3-5]. This approach is also critical to validate theoretical research, which recommends culturally relevant curriculum and pedagogies as a method for making STEM education more accessible to American Indian students however; empirical research on these practices is missing[6-7]. A challenge with validation is that Tribal communities generally distrust the research process used to inform educational methods due to a history of abusive research practices[8-9].

One way researchers are restoring and strengthening relationships with American Indian communities is through Community-Based Participatory Research (CBPR). This research methodology engages the community in an equal partnership to conceive of and carry out research in support of shared goals[10-12]. In this paper we presents a project in which a University and a Tribal community collaborate to employ a CBPR methodology to facilitate a three-year NSF funded grant that aims to provide culturally integrated STEM experiences for tribal youth in grades 4-6. The grant goals are to increase students' knowledge and attitudes about STEM content by conducting summer camps at places of tribal significance. This provides tribal youth with an opportunity to learn about the relevance of STEM in their community by engaging them in the development of engineering solutions to local environmental problems.

This case study focuses on the first half of the grant, specifically the curriculum development and implementation for the first-year summer camp, and the post-camp reflections. The following objectives guided this study, specifically to describe: 1) how the CBPR methodology is applied to develop and implement a culturally relevant STEM curriculum that emphasizes engineering, 2) the impact of the summer camp experience on student's knowledge and attitudes about STEM content, and 3) how the CBPR methodology is used to facilitate partnerships and relationships with the community. We address these objectives using multiple data sources and observations to define the case study activities. We then consider the impact of the camp on students by qualitatively assessing student camp surveys. Qualitative assessment of community data sources (i.e. reflections and surveys) guided the grant partners in evaluating the application of the CBPR methodology for building community relationships. These reflections are summarized as *lessons learned* and include plans for modifying the research approach to strengthen the partnership and support tribal youth.

Background

A long history of unethical and abusive research practices have led American Indian communities to distrust and even refuse to work with researchers1[2-14]. In some cases, research

has harmed American Indian communities, as was the recent experience for the Havasupai Tribe. Researchers working with this tribal community distributed collected blood samples to other researchers across the country without informed consent or permission from the original tribal members and then conducted research unrelated to the original study[8]. While some of these researchers received grant funding and degrees misusing the blood samples, the tribal community never received a summary of the original research findings, which could have provided insight into a community health concern. When the tribe learned of the unauthorized research, some of which had been published and was at odds with tribal values, the tribal community successfully sued the original lead research institution[13]. Experiences similar to the one described have resulted in tribal communities distrusting more traditional western research practices where the university or institution operate in isolation from the research subjects[10,15].

CBPR has emerged as a "method for changing this negative history into a positive future" (p. 71)[16] by engaging American Indian communities in all aspects of the research process1[1-12]. The CBPR methodology is a "participatory research" approach, which has a core philosophy of inclusivity, emphasizing community engagement in the design of research that responds directly to the community's needs[17]. CBPR shifts the concept of research from "one in which the community is a 'laboratory' for investigation" (p. 5)[11] to one in which "research is by and with a community rather than simply for or about a community" (p. 23)[17]. This methodology expands scientific inquiry to include goals for empowering and building community capacity by utilizing local knowledge to promote research solutions from the participants most affected by potential actions generated within the research[17]. CBPR is an iterative process in which academic researchers and community partners develop research projects through collaboration, collecting and analyzing data while making iterative refinements to the research project[16]. CBPR generally emerges from community partners who want to have an active voice in framing the research. Through the collaborative and systematic collection and analysis of data, community partners reflect, adjust and improve the project or research program development and implementation. An added benefit is that the CBPR methodology provides training opportunities for community members to develop research skills, thereby empowering them to develop other research-based projects and initiatives independently[17].

Most commonly, literature about the CBPR methodology focuses on community health projects and to a lesser extent on natural resource management projects; however, no documentation of CBPR for educational research was located. For education research, CBPR has the potential to build the community partnerships and engagement essential to support and validate theoretical research, which recommends culturally relevant curriculum and pedagogies as an approach for making education more accessible to tribal youth. Improving STEM education is especially critical now considering that current educational reform efforts have failed to affect the number of STEM degrees awarded to American Indian students[2,18]. Increasing the American Indian representation in STEM is particularly important since a disproportionately large number of stream restorations needs involve water bodies on reservations and for tribal communities, successful restoration is essential to preserve their culture as well as to maintain sovereignty[19]. However, restoration of native land and water bodies requires skills that integrate best-known engineering and science practices with practices that honor traditional native cultures and values[20]. Given that, the national high school graduation rate of American Indians is 51% and the

college graduation rates in STEM fields is 0.8%[2], non-natives who are not vested in tribal perspectives and values typically fill tribal STEM positions.

To help build a STEM workforce that honors tribal culture and values, more American Indians are needed in tribal technical and leadership positions. The desire to build a STEM work force has led tribal communities to seek theoretical approaches that include; integrated place-based curricula, those that combine western STEM concepts with indigenous knowledge, cultural traditions, and tribal values[3-5,21]. One challenge with this approach is tribes traditionally pass knowledge down from generation to generation, through oral storytelling, and as a result, there is generally a lack of written resources on these topics[22]. Since the majority of teachers in tribal schools are non-native and primarily trained to teach western STEM[23], for tribal knowledge to be represented in the curriculum it is essential for community members to become active participants in their youth's education. Thus, a CBPR methodology has the potential to successfully support educational research and build a STEM workforce within American Indian communities.

The Case Study

The case study is part of a three-year NSF funded project, "Back to the Earth (BTTE)." BTTE was developed in partnership between the University of Idaho and two Tribal Communities located in the Inland-Northwest. It focuses on the collaboration with one of the communities and describes the first year summer camp experiences, specifically the curriculum development, implementation, and post-camp community reflections.

The grant goals are to engage tribal youth in grades 4-6 in an integrated STEM experience that merges indigenous knowledge with western understandings at places with cultural and historical significance to the community. The intent of the grant project is to provide Tribal youth an opportunity to deepen their connection with their aboriginal land. A regional watershed provides the context to explore watershed monitoring and health through student engineering challenges. The BTTE curriculum incorporates interdisciplinary, place-based lessons on watershed, ecosystems and natural resource management.

Curriculum Development

A working group primarily developed the curriculum, which included the University, tribal members, community teachers, and technical specialist from the tribal Natural Resources, Fish and Wildlife departments. The iterative curriculum development process started with collecting the community's ideas over the course of multiple meetings. From these, the University created draft curricular documents, which were distributed for community comment. Finally, the University revised the documents based on community input. Because the grant was to the University, the University team initiated and facilitated the meetings, which included both large and small group video conferences, as well as in-person meetings. All grant partners were informed of the curriculum development status through monthly project video conference calls, newsletters, and email updates.

Curriculum Activities

The overall goal of the curriculum development was to create activities and lessons for a four-day informal STEM curriculum in a summer camp setting. Integration of culture, history, and environmental topics was facilitated by the process detailed in the paper *How Land Use Change, Changed Culture*[24]. The theme for the Year-One camp was the 'Ecological Engineer,' with a curricular focus on stream restoration. Figure 1 illustrates the curriculum theme elements and integration process. Camp activities emphasized the beaver's role as an ecological engineer and focused restoration efforts on creating conditions to invite the beaver back allowing natural ecosystem processes to support stream restoration. During the camp students learned how land use changes affected both the environment as well as cultural activities.

For the first three days of camp, students were at the creek, developing a sense of "membership" and connection to the place through hiking, exploring, observing, collecting data, and learning about the historical significance of the place. Tribal community members were invited to visit the camp and share with the students the tribe's current stream restoration goals, tribal stories, and historical events related to the creek. Unfortunately, only a few of the community members attended the camp, which reduced the amount of tribal culture and history content planned during the curriculum development. From non-tribal community speakers, students learned about the beavers role as an ecological engineer in the stream, how beavers natural tendency to build dams can support restoration efforts (for example by reconnecting the creek to the flood plain), and basic needs for beaver survival including food, habitat, shelter, and space. The University taught most of the lessons, included collecting physical and water quality data in conjunction with demonstrations, and discussions regarding the cause and effects of creek erosion.

Students spent the fourth day of camp in the tribal community center and played a stream restoration game developed specifically for them to learn about commonly accepted stream restoration practices, connected with traditional tribal approaches to restoration. After the game students "became engineers," who were challenged to be "stewards" entrusted in the care of the entire creek and "guardians" who restore and protect a specific section of the creek. A first step in their challenge was to use the data they collected during the camp to assess the stream health, to identify problems in the creek, and to develop solutions to those problems by applying what they learned at the creek and from the stream restoration game. Students developed engineering designs in teams of three or four by building a clay model of the creek on a tray and natural materials. Once the groups completed their stream restoration models, the students stood in front of the community and took turns describing their team's restoration design.

The camp activities emphasized the following tribal values, which represent the key visionary leadership components that the tribe is integrating into their youth's educational system[25].

- Membership - relationship with place and people
- Scholarship - the application and pursuit of knowledge
- Guardianship - protection of resources
- Stewardship - care for resources

Scholarship was emphasized as students learned and applied knowledge about; their place, their culture, and the environment as well as the other camp curricular activities

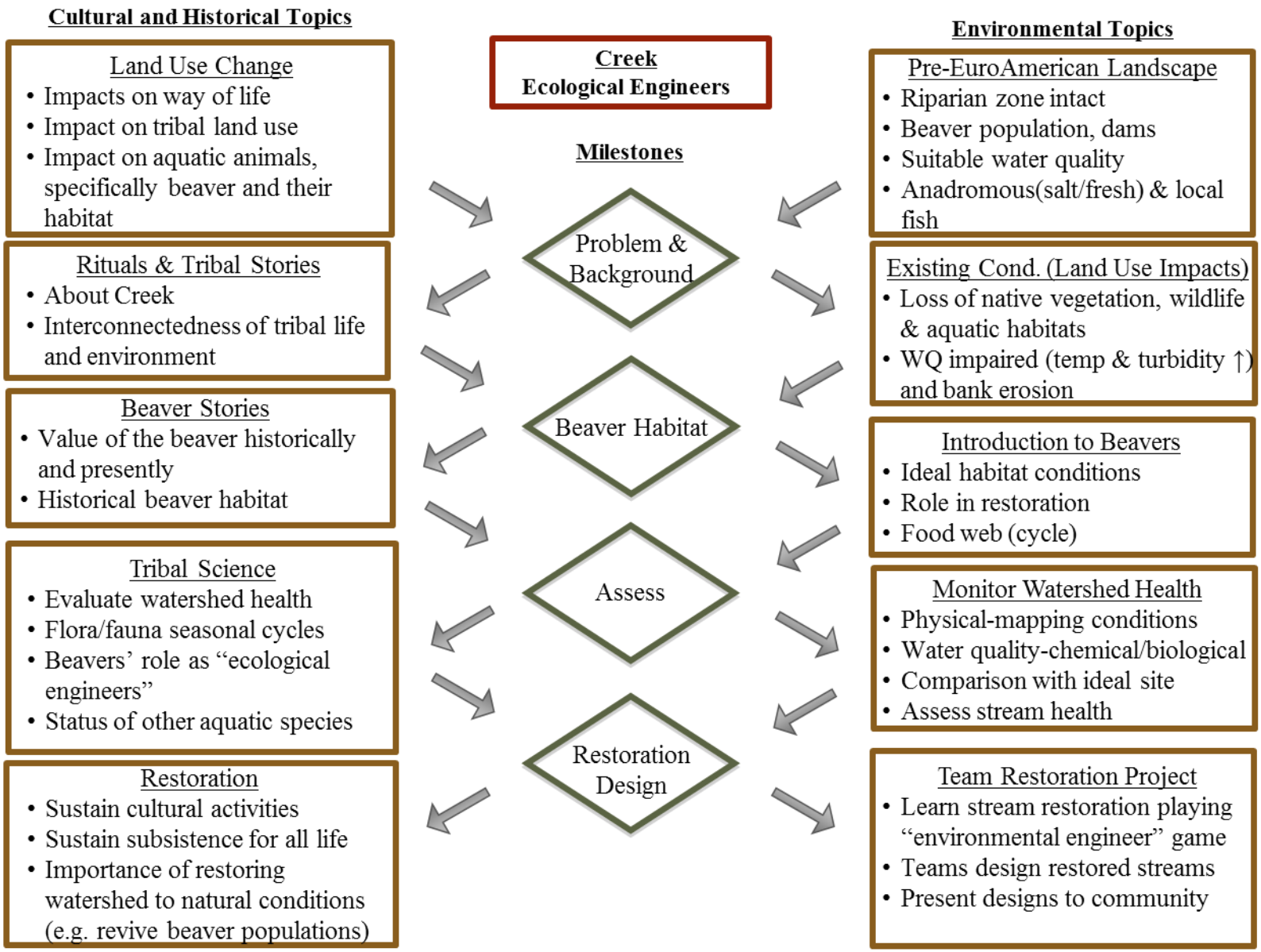

Figure 1. Curriculum Framework

Research Methods

The objectives of this paper were assessed in two parts as subsequently described.

The impact of the camp on students was assessed using the student pre and post camp survey responses. Qualitative analysis of the data included: 1) transcription of the data sources, 2) compiling the responses by data source and question, 3) reviewing and coding the data to determine patterns within the responses, and then 4) regrouping the coded responses into themes. Once one researcher reviewed the data and identified the themes from the coded responses, these themes were shared and discussed with another project researcher. The two researchers met to discuss the coding and meanings within the themes in comparison to the data responses. Ultimately, both researchers agreed on the codes relative to the content and general themes.

The lessons learned were developed using multiple community data sources including; surveys of adult community members, community curriculum development meeting minutes, observational notes from camp, and informal meeting notes. The qualitative analysis of the data used to develop the *lessons learned* was the same as previously described with the exception of the identification of the main topic or theme for each *lesson learned*. In this case, a tribal leader first selected themes based on reflective discussions with the community and University about the first year curriculum development and implementation. Using these themes as a guide, the data was coded. Once the lessons learned were drafted, two community members then reviewed the *lessons learned* which were modified based on their comments.

Students

Ten 4-6 grade students from the tribal community attended a four-day long camp. Each participant completed the same survey both pre- and post-camp. Of the ten participants, nine completed the pre-camp survey and all ten completed the post-camp survey. The pre- and post-camp surveys consisted of the open-ended questions shown in Table 1, which were designed to assess changes in students' attitudes toward STEM.

Table 1. Student Pre- and Post-Camp Survey Questions

1a. 1b.	What have you ever heard about the Creek? Who did you learn this from?
2.	What do you think engineering is?
3.	Do you think science, mathematics, & engineering can help your community?
4.	What do you want to do after high school?

Community

In total approximately twenty community members provided feedback used to develop the themes for the lessons learned. This included four community members who responded anonymously to an online survey and an average of eight community members who attended monthly curriculum development meetings. For this paper, the community is defined as those who were either indirectly or directly involved in the summer camp, including: parents of camp participants, community teachers, tribal members, and nontribal members either living on the

reservation or working in a STEM-related job for the Tribe (such as Department of Natural Resources). Directly involved is defined as participating in the planning and/or implementation of the camp curriculum, and indirectly involved is either a parent or guardian of a child who attended the camp.

University Researchers

The university research team consists of three professors and three graduate students from both education and engineering departments as well as one external evaluator. None of the university researchers are tribal members. All but one member of the university research team attended the camp and activily engaged with the students.

Findings

Students

Overall, the student data indicates that the summer camp had a positive impact on students attitudes toward STEM based on the enthusiastic responses about the BTTE program activities, especially students noting that they liked "being in the creek," hands on engineering projects, and meeting “real life” engineers. A concern expressed by adult community members was that the (pre and post) instruments developed to provide "evidence" were not designed to measure increases in STEM content knowledge. Further discussions of these concerns are presented in the *lessons learned* section of this paper. The remainder of this section is a more detailed description of the student responses to the pre- and post-camp data.

Pre-camp surveys indicated that only two students knew something about the creek and which was learned from a parent or community teacher. Only one of these provided historical tribal details, and neither described environmental concerns. In the post-camp surveys, eight students indicated knowing something about the creek, four included historical tribal details, and three mentioned environmental issues. Students indicated in the post-camp survey that they gained this knowledge from the BTTE camp.

When asked to define engineering in the pre-camp surveys, six students provided definitions that included the concepts of building, designing, and inventing. The post-camp responses were nearly identical with six students providing definitions that included the concepts of designing, building, and/or making something. One significant change from pre- to post-camp was that four students noted how engineering helps or benefits others. In addition, four students demonstrated a change in their perception about how STEM is relevant to their communities.

In regards to how the camp may have affected students’ attitudes about STEM, students were asked to describe their post high school plans. While the majority of the students provided the same answer before and after the camp, three students demonstrated a new interest in a STEM career, and two of those students envisioned working as an engineer.

Community Lessons Learned

Overall, the primary theme that emerged from the community responses was that the community did not feel like an "equal" partner on the grant. These responses indicate that the first year University application of the CBPR methodology did not realize the full development of a community partnership. In addition, this issue appears to have affected the relationship between

the University and the community in that some community members were less involved in the curriculum development and implementation resulting in camp activities with less tribal and cultural relevance. Since the CBPR methodology is an iterative approach, grant partners can make refinements throughout the research project in pursuit of shared goals.

It is essential to note that there are 560 federally recognized tribes in the United States, and while tribal communities have similarities, every tribe is unique. Therefore, while the lessons learned described in this section may provide researchers with insight and guidance into similar projects with American Indian communities, they should not be viewed as generalizable to other tribal communities.

1. Communication
   The most prominent theme identified in the community data was the need for better communication. While the University felt they were effectively communicating with the community, it was apparent from listening to and reading the community feedback that the community did not agree. Each community member had different perspectives about where the failure in communication occurred, and various suggestions for improving communication were provided, as such, the communication lessons learned are presented to focus on the respective group.
   - Parents - Most parents indicated that they wished communication had been better with respect to notifying them about the camp before it began, providing them with information about who was supervising the camp, and giving them feedback about their children's specific activities. The parents made several useful suggestions for improving communication during the year two camp as described in this paragraph. To better advertise the camp, the University plans to produce and distribute an informational brochure summarizing camp activities, including a day-by-day schedule of activities, a calendar of planned camp events, and camp personnel biographies. In addition, multiple modes of communication will be used to inform parents about what their children were doing each day at camp, including morning emails to highlight the day's events, having campers create a daily blog about what they did, and sending home pictures of their children actively participating at camp.
   - Community Leaders - During the camp, the community leaders were not as involved as originally planned. Specifically, some tribal community speakers did not show up. The goal of including these speakers in the camp activities was to integrate the curriculum topics with the cultural relevance by; tying stream restoration topics to tribal history, tribal values, and indigenous knowledge. For example, students learned from a non-tribal community member about the beaver's role as an ecological engineer in stream restoration. They learned that the tribe had elected to focus restoration efforts on creating suitable beaver habitat conditions to encourage the beavers to build dams to reconnect the stream to the former flood plain instead of using engineered solutions. To make the lesson more culturally relevant, a tribal speaker was to teach the children about the significance of the beaver to the tribe and explain how allowing the beaver to be the ecological engineer honors tribal values. While tribal youth still learned about the beaver's role in the restoration process, they were taught by a nontribal member, which reduced the planned amount of tribal historical and tribal content originally planned.

The community leaders who were tasked with arranging for these speakers later indicated this issue resulted from poor communication from the University in that they did not understand what was being asked of them. In year one, the university approach was to task community leaders who were part of the curriculum working group to secure tribal experts as speakers. The problem was that they were not informed of the presentation context or content. For year two, the modified approach has been to work collaboratively to determine the specific purpose of the speaker as well as the topics for speakers to address, and then allow the tribal community selects the best community member to speak with the youth.

2. Identify the Community
   The tribal communities' involvement on the grant was not clear to themselves or to the University. As a result, the tribal community questioned their roles in the project, and the University was uncertain about whom from the community to invite to meetings and include in correspondence. This led to confusion regarding expectations, as succinctly expressed by a community member, "all of us were confused." It is thus essential to both identify who represents the community and their roles. With that, the University learned that the community is best suited to identify community members with the strengths needed both to support the development of the curriculum framework, and to serve as speakers during the camp. For example, tribal community teachers can play a key role in ensuring that the curriculum is grade-appropriate.

3. Meeting Protocol
   Initially, regular meetings with the community were held via video and teleconference, and infrequently meetings were face to face. This was not always effective, in part due to technical issues. While this format seemed effective for the University in an authoritative role, it simply was not engaging to or accessible by the communities. Instead, face-to-face community meetings have been more effective, and valued by tribal representatives. In the second year of the grant, the University has approached meetings as a partner rather than as the meeting leader. For example, meetings have been co-lead by the community members and meeting agendas have been a collaborative endeavor and now focus on goals rather than tasks. In addition, considering that tribal communities tend to value listening over speaking[26], the University has focused on doing more listening than talking during meetings. These changes have helped to create a more balanced perspective and a listening environment where all grant partners feel their voices are heard and valued. These changes have also resulted in a higher community attendance rate at curriculum development meetings.

4. Partnership in Developing the Curriculum Framework
   During the first year, the curriculum development followed a business model or authoritative approach to lesson planning and instruction rather than a fully inclusive CBPR methodology. For example, the university collected multiple ideas from several meetings with the community, and then based on one-way interpretation of tribal community ideas; the University developed the curriculum framework shown in Figure 1. When the community attended the curriculum development meetings, where they thought they would be collaboratively developing the curriculum, they instead heard the University present their decisions regarding the development of the curriculum framework. While the University felt

they had collaboratively developed the curriculum framework, this approach caused the tribe to feel like a "guest" at the curriculum development meetings, as opposed to a full partner.

As one community member described, the year-two curriculum development started with:

> "...being rooted in Traditional knowledge *first* with goals and objectives always stemming from that as a starting place"

For example, the year-two development of the curriculum framework started with the community selecting places and topics they want their youth to learn about; culture, the environment, tribal history, tribal values, and indigenous knowledge. The University plans to inform the process with knowledge of STEM content and pedagogical methods. In addition, the community plans to identify the curriculum learning outcomes and participate in the creation of an assessment tools to evaluate those learning outcomes. Once the curriculum framework is developed, the University will draft lesson plans with the tribal community teachers, followed by an iterative community review process, with the intent of having the final curriculum approved by the community. The plan is to continue collaboration throughout curriculum implementation and evaluation in order to ensure that tribal goals continue to be met, and to build the community capacity in curriculum development and evaluation.

5. Communities Must Benefit

The purpose of educational research is "to advance knowledge about education, to encourage scholarly inquiry related to education, and to promote the use of research to improve education and serve the public good"[27]. Typically, data collected as part of educational research is used to address research questions, and to write and publish papers. This ultimately benefits the researcher and improves the practice of education. Although some funding institutions such as the National Science Foundation (NSF) require dissemination of the research and evaluation findings[28], in CBPR projects, research is only considered ethical if the community receives adequate benefits from the research[10]. For example, after the first summer camp, the community became frustrated when the University appeared to be placing a priority on using student data to publish papers instead of utilizing the student data to improve the year-two camp curriculum, and to create sustainable culturally relevant curriculum for the community teachers to use. In year two, the community and university are beginning to collaboratively review the collected data and verify that the tribal youth are progressing toward achievement of the learning outcomes. If the results do not demonstrate progress, then the University will immediately implement a corrective action to ensure that the future curriculum development and assessment will align with the learning objectives.

6. Engineering Informed by Tribal Values

While technical competency and ethical responsibility are essential for engineers[29], to be consistent with American Indian values, restoration of tribal land must consider traditional knowledge, and long term resource planning[20,30]. Most engineers consider budget and schedule as key to developing engineering solutions. However, on tribal projects these are typically considered secondary to implementing sustainable solutions that will benefit the next seven generations. For example, an engineering consultant for the tribe conducted a detailed assessment and preliminary creek restoration design that relied on structural solutions (such as riprap). The tribe decided against this quick-fix approach, instead choosing

to rely on the beaver as a resident ecological engineer. For STEM education researchers working with tribal communities, it is essential that the curriculum be grounded in tribal culture and values. The community's desire is that their youth be prepared to stand in two worlds: one in one in which tribal values are fully honored and on in which they apply the best practices of western STEM knowledge.

Conclusion

Engaging tribal communities in education is critical to validate theoretical research, which recommends culturally relevant STEM experiences to inspire student learning and promote American Indians students in STEM fields. This is essential to support restoration of tribal water bodies and preserve cultural activities, which depends on engineers who are prepared to integrate best-known restoration practices (of western STEM) with practices that honor tribal values and culture. Considering the history of abusive research practices, CBPR methodologies have the potential to validate theoretical research, which could support community goals, by building community relationship and engaging the tribal community in all aspects of the research process.

This paper describes a case study where a University and a Tribal community applied a CBPR methodology to facilitate a research project focused on; the curriculum development, implementation, and post reflections for a culturally relevant STEM summer camp. Assessment of student surveys indicates the summer camp experience increased attitudes about STEM and helped students see engineering as relevant and beneficial for their community. While these findings support theoretical research, it is too soon to make conclusion with respect to engineering education considering the findings reflect the responses of only 10 students at single summer camp and there was insufficient evidence to determine if students' knowledge increased with respect to STEM content.

While the University attempted to utilize a CBPR methodology to develop community relationships, based on community responses it was apparent the Tribal community felt the partnership with the University was not equal. Using the iterative process of the CBPR, grant partners develop the *lessons learned* which served as a plan for making improvements to the research project. At the time this paper was written, the grant partners had implemented many of the *lessons learned* for the second year of the BTTE project. Based on preliminary and informal oral feedback from the tribe, it appears that the modifications to CBPR more effectively support relationships with the community. This improvement is essential to provide tribal youth with a more culturally relevant STEM experience during the year-two camp, create assessment tools that effectively measure student learning, and reflect tribal values.

Overall, using the CBPR process has been a learning experience for all grant partners. A tribal leader best summarized the experience stating:

> We are on a journey—trying to support our youth's STEM education in collaboration with the University. I believe there have been many positive *lessons learned*. Our partnership survived, due to our focus on youth and wanting the best for them. We have been able to communicate openly and honestly and we are learning from each other.

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