

Participatory Design Based Research with Native American serving Middle Schools

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Abstract: Professional development in Native American serving schools is evolving and having improved results via participatory design-based research. Instead of starting teacher education projects with an entirely set curriculum; design-based research utilizes iterative rounds of curriculum development and re-design by using feedback from participating teachers, community advisors, instructors, and project partners. This paper describes how design-based research principles were applied within a research project focused on STEM education in Native American serving middle schools and the preliminary results of doing so.

Introduction/Study Context

The goal of Project CoSTEM is to promote STEM self-efficacy and career interest among Native American students through relevant and meaningful experiences with integrated STEM community-based projects during their critical development years in middle school. There is strong evidence that options/decisions to pursue STEM careers/studies are solidified by the start of high school (Woolley, Strutchens, Gilbert, & Martin, 2010; Tai et al., 2006; George, Stevenson, Thomason, & Beane, 1992; Berryman, 1983). If students do not express an interest and feel confident in pursuing STEM subjects by the time they leave middle school, they are less likely to choose electives in STEM disciplines in high school and/or pursue STEM related job opportunities or internships (Misiti, Shrigley & Hanson, 1991). The drop-off in STEM subject interest and achievement by the end of middle school / early high-school is even more apparent among students from Under-Represented Minority (URM) groups in STEM (Maltese & Tai, 2011). For this reason, Project CoSTEM focuses on reaching students from the northern Arizona and New Mexico areas at the critical years in middle school, providing them with positive, relevant experiences with STEM that support their growth as learners and interest in STEM professions before entering high-school.

Theoretical Framework

The theory of change (Figure 1) guiding this project is that strategic partnerships between education and cultural leaders from the Native American areas of interest, STEM professionals, and advisors with experience in developing culturally responsive curriculum support (1) the development of collaborative working group meetings to (2) collaboratively develop guidelines for culturally competent STEM education for Native students. The work of these partnerships is applied to the development and implementation of a teacher professional development program in which (3) teachers design culturally-responsive technology-rich project-based curriculum (4) the experience of which increases their personal sense of self efficacy and interest in designing culturally competent technology driven learning experiences for their students. When the teachers implement the units/curriculum in their classroom, (5) students gain the experience of a culturally and community relevant and meaningful STEM learning experiences which (6) supports and increases their sense of self efficacy as STEM learners and future career professionals.



Figure 1. Theory of change to increase interest and self-efficacy as STEM learners

Literature review

The CoSTEM project draws from research on four key educational strategies that have individually shown promise to increase STEM achievement and interest for K-12 students. This project combines these strategies into a unified approach specifically targeting a critical URM population, Native American middle school students. The four key research-based STEM education strategies are 1) Sustained teacher professional development and support, 2) Contextualize STEM in culture and community, 3) Technology- driven interdisciplinary STEM approach, and 4) Project-based learning.

1) Sustained Teacher Professional Development & Support - Professional development and support that is sustained over a longer term is more likely to lead to changes in classroom practice and ultimately to changes in student learning, when compared to short term or isolated workshop/trainings. The CoSTEM project professional development aligns with the components of high-quality PD outlined in the seminal report by Darling- Hammond (2009) that identified the characteristics of effective professional development as; a) intensive, ongoing and connected to practice, b) focused on student learning and specific curriculum content, c) aligned with school improvement priorities, and d) includes opportunities for collaborative teacher planning networking and problem solving.

2) Contextualize STEM in Culture and Community - Embedding learning in a cultural context and frameworks has been shown to increase student achievement and engagement, specifically among Native American students (Searle & Kafai, 2015; Kafai et al, 2014; Hopkins, 2009;). Theme-based and locally situated STEM tasks have additionally been shown to increase student interest and engagement in STEM learning (Stevens, Andrade & Page, 2016). Similarly, incorporating Native American cultural frameworks in professional development for teachers has led to improved educational outcomes among Native American students (Dubiel, Hasiotis, & Semken, 1997).

3) Technology-Driven Interdisciplinary Approach to STEM teaching and learning - Interdisciplinary STEM engages students in content and practices from multiple disciplines as part of a single curricular unit or lesson. When technology drives the purpose and process for interdisciplinary STEM learning, students have improved their dispositions towards technology and disciplinary achievement in STEM (Chiu, Price & Ovrachim, 2015; Judson, 2014; Sherrod et al. 2009). Students with low achievement in math and science, when engaged in technology-driven approaches to interdisciplinary STEM, have demonstrated greater increases in achievement than high-achieving students (Kajamies, Vauras & Kinnunen, 2010). Technology- driven opportunities have also shown success with students from backgrounds underrepresented in STEM and Native American students specifically (Kafai et. al, 2014). The higher order thinking skills and habits of mind that students develop in technology-driven integrated STEM learning environments are prerequisites for student's success in college and careers and further support increased academic achievement across the disciplines (Johnson, Peters-Burton & Moore, 2015; Bybee, 2013). An interdisciplinary approach to STEM is also more reflective of the real-world work of STEM professionals, further preparing students for careers in STEM (Roehrig, Moore, Wang, & Park, 2012).

4) Project Based Learning (PBL) - Project based learning is a teaching method in which students gain knowledge and skills by working for an extended period to investigate and respond to an engaging and complex question, problem or challenge (Buck Institute for Education, 2015). When compared with teachers using a traditional lecture driven approach to instruction, teachers who use a PBL approach are more likely to teach and assess 21st century skills (such as critical thinking and problem solving) and have shown increases in student learning and achievement (Hixson, Ravitz, & Whisman, 2012; Geier et al., 2008). The PBL approach has also been shown to reduce linguistic, ethnic, and class inequalities in middle and high school achievement (Boaler, 2002; Penuel & Means, 2000).

Objectives

The goal of Project CoSTEM is to promote STEM disciplinary self-efficacy and career interest among youth from the Navajo Nation area through relevant and meaningful experiences with STEM during their critical development years in middle school. To accomplish this goal, the project is designed to meet the following objectives:

Objective 1: Increase student access to culturally relevant STEM through collaborative development of guidelines for culturally-responsive STEM education, in partnership with Project CoSTEM education leaders and STEM professionals.

Objective 2: Increase teacher competence and confidence in designing and implementing culturally responsive, technology-focused, interdisciplinary STEM instructional units (curriculum) for students.

Objective 3: Increase student interest and efficacy in STEM.

Methods

The CoSTEM project utilizes a Design-Based Research (DBR) methodology, with three iterative cycles of design. Research and evaluation are used to assess the impact of learning and identify factors that mediated learning in order to improve the intervention with each new round of implementation. This research includes the following key characteristics of DBR: a) Takes place through iterative cycles of design, enactment, analysis, and redesign, b) Documents connections between the enactment processes and outcomes of interest, c) Documents successes or failures in authentic settings and, d) Leads to shareable design principles or strategies that help practitioners and educational designers (Design Based Research Collective, 2003).

As part of DBR's iterative design process during the second year, the project partners developed version 2 of the professional development training, building from lessons learned, teacher input, advisor input, and collaborator input on version 1. Key challenges identified in Design Cycle 1 (version 1) led to targeted revisions to the professional development content and structure in Design Cycle 2 (version 2). The identification, revision, and testing of these challenges and strengths is part of the larger process of creating a set of Design Principles for the PD model that we intend to disseminate broadly at the end of the project (Design Cycle 3).

Key Challenge #1: Inconsistency in available data led to inconsistency in use of data by teachers in their classroom projects with students.

Revision: Through partnership with the Indigenous Tribal Environmental Professional (ITEP) center at Northern Arizona University, version 2 of the Professional Development (PD) and resulting teacher projects/units for the classroom drew from data collected first and second hand through Purple Air remote air quality sensing devices. This allowed PD instructors to focus PD sessions on the strategies for developing projects around air quality data and ways to use technology to engage students with the data.

Key Challenge #2: Open-ended project structuring created challenges for teachers with less experience in unit-development and wide variability in level of project implementation.

Revision: The second version narrowed the focus of the model lessons and units presented in the PD training to focus on community air quality to allow for greater levels of collaboration among teacher participants across a broad region. The PD sessions were structured to intersperse school/teacher small group meetings and asynchronous classroom implementation activities to allow for a strong level of support from colleagues and instructors in the implementation process. The content of each of the sessions remained focused on the core project components: project-based learning in STEM (with integrated disciplinary focus), technology-supported data science and data-based investigations in STEM using the Common Online Data Analysis Platform (CODAP) (Finzer et al., 2018), and community/culturally responsive STEM pedagogy and practice. However, in version 2 the PD demonstrated how each of the project components could be applied through a project/unit focus on community Air Quality data collection and analysis. To further support the narrowed focus, we developed a Purple Air plugin for CODAP to allow all participant teachers and their students to download Purple Air data directly into the platform.

Key Challenge #3: The interdisciplinary nature of projects (and teaching contexts of project participants) requires more and varied opportunities to engage with data analysis technologies in ways that are a fit for each individual classroom teacher and disciplinary context.

Revision: The project team identified the need for simultaneously narrowing and broadening across the PD model and structures. The narrowing of the project to focus on air quality supported interdisciplinary planning, with each content area teacher focusing on a different aspect of air quality (science, mathematics, social studies, SPED, etc.). The team also identified a need to expand the opportunities to engage with different types of technology that best supported each of the disciplinary contexts. In version 2, instructors used education technologies (Desmos and CODAP) to allow for broader and more relevant engagement experiences.

Results

During the first round of implementing professional development, participating teachers experienced examples of three research-based STEM education strategies as learners (Contextualized STEM in culture and community, Technology-driven interdisciplinary STEM approach, and Project-based learning) and were supported in planning lessons for their students that specific to their classrooms and schools. Participants struggled to find time to integrate these ideas into their practice at a consistently deep and meaningful level. Table 1, below, shows

how evaluators rated participant STEM lessons on a 4-point scale of how well the lessons aligned with CoSTEM core components (0-Did Not Meet, 1-minimally met, 2-mostly met, 3-fully met).

<u>Project Title</u>	<u>Context</u>	<u>Data Science</u>	<u>Interdisciplinary</u>	<u>PBL</u>	<u>Technology</u>
Creating a Custom Wooden Cabinet	1	2	2	1.5	2
Growing Sustainable, Indigenous Drought-Tolerant Plants	2	2	2	2	2
Impact of Human Activities on the Greenhouse Effect	3	3	3	2	2.5
The Past and Future of Our Planet	1	2	2	1	1
Water Quality	2	2	2	2	2
Water Quality and Water Usage	2	2	2	2	2.5

Table 1. Year One Project CoSTEM Core Component ratings

Upon analysis and reflection, participants, instructors, project advisors, and community members decided that a context that all found engaging and relevant (air quality) would provide more structure for participating teachers to be able to apply these project CoSTEM core ideas to their own classrooms. Year Two of CoSTEM, therefore, decided to partner with the Indigenous Tribal Environmental Professional (ITEP) center (<https://www7.nau.edu/itep/main/Home/>) in disseminating Purple Air sensors to participants so they could gather data about air quality locally in their area. Furthermore, the CoSTEM team developed a CODAP Purple Air plugin so teachers and their students could quickly gather air quality data for the STEM investigative units (<https://tinyurl.com/3c5mxpbb>) participating teachers developed for their classrooms. Resulting analysis of Year Two lessons demonstrated growth in application of core Project CoSTEM ideas (see Table 2, below).

<u>Project Title</u>	<u>Context</u>	<u>Data Science</u>	<u>Interdisciplinary</u>	<u>PBL</u>	<u>Technology</u>
Air Quality Investigation	2	3	2	2.5	3
Investigating Temperature and Air Quality	2	2	3	2	2
Raising Awareness about Air Quality in your Community	2	3	2	2.5	3
Investigating Air Quality in Window Rock	2	2.5	2	2	2.5
Investigating Data in Kayenta	2.5	2	2	2	2
Investigating the San Francisco Peaks Environment	2.5	2.5	3	2.5	2.5

Table 2. Year Two Project CoSTEM Core Component ratings

As can be seen from the results shared above, CoSTEM project objectives 1 and 2 have been met during the first two years of the project and we are optimistic we will continue to see growth in these areas. Due to COVID and strict Navajo Nation research guidelines, we are still in the process of gathering and analyzing student data, which will occur during Year Three of project CoSTEM.

Discussion/Implications

The CoSTEM project has the potential to advance knowledge regarding tools and strategies for transforming STEM teaching and learning experiences for Indigenous/Native American students. To our knowledge this is the first effort to design and apply STEM based curricular guidelines for middle schools that predominantly serve Native American students. The research findings related to the effectiveness of using co-created guidelines for cultural competence to guide the design of teacher professional development and student curricular units can be used to inform the development of STEM education models for other under-represented minority groups in STEM. We expect to find that the layered focus on cultural competence and creation of data-driven visualizations will continue to inform the development of teacher professional developments that foster student interest and efficacy in STEM through technology-rich, culturally relevant, and community focused projects.

Project activities have improved participating teacher's competence and confidence in working with technology in their classrooms in a way that is responsive to the cultural frameworks and perspectives of their students and communities. Project deliverables (guidelines, PD model, and STEM units) will be available to education leaders and practitioners across a broad region to support their own transition to culturally competent STEM. We hope that the success of Project CoSTEM can lead to larger scale-up efforts to transform STEM

education policy and practice for schools/districts serving Indigenous/American Indian students. Improving STEM interest and efficacy among Native American/Indigenous students is critical to increasing diversity and representation in the STEM workforce.

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References

- Berryman, S. E. (1983). *Who Will Do Science? Minority and Female Attainment of Science and Mathematics Degrees: Trends and Causes*. Rockefeller Foundation.
- Boaler, J. (2002). Learning from teaching: Exploring the relationship between reform curriculum and equity. *Journal for research in mathematics education*, 239-258.
- Bybee, R. W. (2013). *The case for STEM education: Challenges and opportunities*. NSTA press.
- Chiu, A., Price, C. A., & Ovrachim, E. (2015, April). Supporting elementary and middle school STEM education at the whole school level: A review of the literature. In NARST 2015 Annual Conference, Chicago, IL.
- Design-Based Research Collective. (2003). Design based research: An emerging paradigm for educational inquiry. *Educational Researcher*, (1), 5-8.
- Dubiel, R. F., Hasiotis, S. T., & Semken, S. C. (1997). Hands-on geology for Navajo Nation teachers. *Journal of Geoscience Education*, 45(2), 113-116.
- Finzer, W., Busey, A., & Kochevar, R. (2018). Data-driven inquiry in the PBL classroom. *The Science Teacher*, 86(1), 28-34.
- George, P. S., Stevenson, C., Thomason, J., & Beane, J. (1992). *The middle school—and beyond*. Alexandria, VA: Association for Supervision and Curriculum Development
- Geier, R., Blumenfeld, P. C., Marx, R. W., Krajcik, J. S., Fishman, B., Soloway, E., & Clay-Chambers, J. (2008). Standardized test outcomes for students engaged in inquiry-based science curricula in the context of urban reform. *Journal of Research in Science Teaching: The Official Journal of the National Association for Research in Science Teaching*, 45(8), 922-939.
- Hixson, N. K., Ravitz, J., & Whisman, A. (2012). *Extended Professional Development in Project- Based Learning: Impacts on 21st Century Skills Teaching and Student Achievement*. West Virginia Department of Education.
- Hopkins, T. T. R. (2009). *Evaluating American Indian and Alaska Native education*.
- Judson, E. (2014). Effects of transferring to STEM-focused charter and magnet schools on student achievement. *The Journal of Educational Research*, 107(4), 255-266.
- Kafai, Y., Searle, K., Martinez, C., & Brayboy, B. (2014, March). Ethnocomputing with electronic textiles: culturally responsive open design to broaden participation in computing in American Indian youth and communities. In *Proceedings of the 45th ACM technical symposium on Computer science education* (pp. 241-246). ACM.
- Kajamies, A., Vauras, M., & Kinnunen, R. (2010). Instructing low-achievers in mathematical word problem solving. *Scandinavian Journal of Educational Research*, 54(4), 335-355.
- Maltese, A. V., & Tai, R. H. (2011). Pipeline persistence: Examining the association of educational experiences with earned degrees in STEM among US students. *Science education*, 95(5), 877-907.

Misiti, F., Shrigley, R., & Hanson, L. (1991). Science attitude scale for middle school students. *Science Education*, 75(5), 525-540. doi: 10.1002/sce.3730750504

Penuel, W.R. & Means, B. (2000). Designing a performance assessment to measure students' communication skills in multi-media-supported, project-based learning. In Annual Meeting of the American Educational Research Association, New Orleans.

Roehrig, G. H., Moore, T. J., Wang, H. H., & Park, M. S. (2012). Is adding the E enough? Investigating the impact of K-12 engineering standards on the implementation of STEM integration. *School Science and Mathematics*, 112(1), 31-44.

Searle, K. A., & Kafai, Y. B. (2015). Culturally responsive making with American Indian girls: Bridging the identity gap in crafting and computing with electronic textiles. In Proceedings of the Third Conference on Gender IT (pp. 9-16). ACM.

Sherrod, S. E., Dwyer, J., & Narayan, R. (2009). Developing science and math integrated activities for middle school students. *International Journal of Mathematical Education in Science and Technology*, 40(2), 247-257.

Stevens, S., Andrade, R., & Page, M. (2016). Motivating young native American students to pursue STEM learning through a culturally relevant science program. *Journal of Science Education and Technology*, 25(6), 947-960.

Tai, R. H., Liu, C. Q., Maltese, A. V., & Fan, X. (2006). Planning early for careers in science. *Science*, 312(5777), 1143-1144.

Woolley, M. E., Strutchens, M. E., Gilbert, M. C., & Martin, W. G. (2010). Mathematics success of Black middle school students: Direct and indirect effects of teacher expectations and reform practices. *The Negro Educational Review*, 61(1-4), 41-59.