Culturally-Relevant Engineering Design Curriculum for the Navajo Nation

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Dr. Jordan co-developed the STEAM Labs™ program to engage middle and high school students in learning science, technology, engineering, arts, and math concepts through designing and building chain reaction machines. He founded and led teams to two collegiate Rube Goldberg Machine Contest national championships, and has appeared on many TV shows (including Modern Marvels on The History Channel and Jimmy Kimmel Live on ABC) and a movie with his chain reaction machines. He serves on the Board of the i.d.e.a. Museum in Mesa, AZ, and worked as a behind-the scenes engineer for season 3 of the PBS engineering design reality TV show Design Squad. He also held the Guinness World Record for the largest number of steps – 125 – in a working Rube Goldberg machine.

Dr. Kalvin White, Department of Dine Education, Navajo Nation

Kalvin White, Ph.D. is from White Cone, Arizona. He earned his doctorate in Counseling Psychology in 1998 from the University of Utah. Dr. White is currently employed with the Office of Dine Science, Math, and Technology within the Department of Dine Education under the Executive Branch of the Navajo Nation Government. Dr. White was the Principal Investigator of the Navajo Nation Rural Systemic Initiative. In 1998 the Navajo Nation received a National Science Foundation grant with the charge to close the achievement gap that exists on the Navajo Nation between Navajo and non-Navajo students in math and science. The NN-RSI documented the closing of the achievement gap at the end of the grant award August 2005. Through the efforts of the NN-RSI the Navajo Nation has sustained the NN-RSI with Navajo Nation funds as the Office of Dine Science, Math and Technology. As such, Dr. White and the staff of the Dine Science, Math, and Technology continue to advance the systemic initiatives within the Navajo Nation.

Ieshya K Anderson, Arizona State University

Ieshya Anderson is Naakétł'áhí (Tohono O'odham), born for Tł'ááshchí'í. Her cheii is Naakétł'áhí and her nálí is Tódích'íi'nii. Ieshya graduated from Arizona State University, Ira A. Fulton Schools of Engineering with a Bachelor of Science in Engineering, emphasis in electrical systems. She is pursuing her PhD in Engineering Education Systems and Design at Arizona State University. Ieshya also continues to work with Dr. Shawn Jordan to develop engineering design curricula for middle school students on the Navajo reservation and facilitates Dr. Jordan's STEAM Machines™ outreach camps across the Navajo Nation with the ambition to expand to Tohono O'odham Nation.

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Work in Progress: Culturally-Relevant Engineering Design Curriculum for the Navajo Nation

The mission of this research is to develop a theory of culturally-contextualized engineering design curricula and assessment tools for Navajo middle school students, grounded in a study of how Navajo students and Navajo professionals experience, understand, and apply engineering design in the context of their culture, community, and society. This foundation will support future educational innovations and illuminate pathways for Navajo students to pursue higher education and careers in STEM. This paper describes the foundation for this research and the current progress in the development of curriculum modules that teach Navajo culture and engineering design side-by-side.

The Navajo way of life and the engineering design process have similarities.

This study was inspired by the similarities between the Navajo way of life, which is a holistic cycle of thinking, planning, living, and assuring/testing (Aronilth, 1992), and an engineering design process (ask, imagine, plan, create, improve (Cunningham & Hester, 2007)).

Diverse perspectives drive innovation in STEM.

With the complex nature of real-world problems, our country needs STEM innovators who can work across disciplines to holistically solve problems in both the workplace and in our communities, such as the NAE Grand Challenges for Engineering (Perry et al., 2008). According to a 2011 NSF-AIHEC reports "adding diverse perspectives to the STEM research, engineering, and education community is critical to building knowledge, in part because scientists need multiple perspectives to drive innovation, solve problems, and present new ideas. Looking at the world in different ways, exploring new realms of thought, and drawing upon indigenous knowledge and ways of learning are all crucial to helping NSF stay at the cutting edge of science" (American Indian Higher Education Consortium, 2011). This is echoed in creativity and diversity literature, which espouses that working in diverse groups increases the range of potential solutions (Bassett-Jones, 2005; Cowan, 1995; Cox, 1994; Jackson, 1992; Johansson, 2006; McLeod, Lobel, & Cox, 1996; Watson, Kumar, & Michaelsen, 1993). We need diverse perspectives in STEM in order to drive innovation.

Attracting more Native American students to STEM is part of the national agenda.

According to a report by the National Academy of Engineering, "the engineering profession needs the perspectives of American Indians… and reservations need the culturally relevant contributions of American Indian engineers" (National Academy of Engineers, 2006). From 2000 to 2009, 0.6% of undergraduate students enrolled in undergraduate engineering programs were Native American (National Science Foundation, 2013a). Tribal Colleges and Universities (TCUs) have increased the number of STEM-related degree programs available to Native American students in North America (American Indian Higher Education Consortium, 2011), but only 7% of students enrolled in TCUs were pursuing STEM degrees in 2009 – 2010 (American Indian Higher Education Consortium, 2012). NSF initiated the Tribal College & Universities Program in 2001 to promote improvement in STEM education programs at Tribal Colleges and Universities (National Science Foundation, 2013b). TCUP has supported a number

of STEM education initiatives to improve curricula (e.g., (Blue, 2012)), facilities, and pathways. Advanced STEM education could play an important role in strengthening community and providing career pathways for Native American students.

Research on culturally-infused math and science curricula shows promise.

There is a well-documented achievement gap in STEM between Native American and Caucasian students (White & Galvin, 2002). One way to close this gap is through cultural infusion programs, which have been shown to "positively impact a student's performance on a standardized achievement test in the area of math" (Galvin, Hopkins, & White, 2005). Students respond more positively to science if it is linked to society (Tobias, 1990), and research shows that if students perceive usefulness they are more motivated to persist in STEM fields (Davis & Finelli, 2007; Pintrich & Zusho, 2007; Wigfield & Eccles, 2000). Therefore, culturally-infused curricula may promote persistence in STEM for Native American students.

Navajo Nation will adopt Next Generation Science Standards, which include engineering.

The Next Generation Science Standards (Achieve, 2013) for K-12 schools in the US include engineering as a disciplinary core idea for middle and high school students, defined as engineering design. The Navajo Nation may adopt Next Generation Science Standards in the future, making this study both timely and necessary to understanding how to teach engineering design in a culturally relevant way.

Current Progress: Initial Curriculum Modules

The curriculum for the first in-school pilot is made up of four curriculum modules, described below.

1. *Introduction to Engineering Design.* This lesson introduces engineering design with stories of Navajo engineers and scientists and the impact they have made in their fields. It then compares and contrasts the scientific method and engineering design process. Finally, students will identify problems they could solve with engineering.

2. *Solution Dissection.* This lesson presents students with an engineering challenge and walks the class through how to use the engineering design process to generate a solution. A design process worksheet is used to scaffold the discussion.

3. *Distance Between the Sacred Mountains: A Lesson in Scale and Proportion.* In this lesson, students measure the distance between four sacred mountains on a map and scale them to the actual distances between the real mountains. Then, students share stories of the sacred mountains, and based on the map determine the distance from each of the sacred mountains to their hometown.

4. *The Great Animal Escape: Portable Livestock Corral Design Project*. In this lesson, students will work in teams to design and build scale models of portable livestock corrals. The scale models will be tested using robotic hamsters that represent livestock, and try to escape from the model. Following the activity, students will reflect on how their individual participation in the group reflects teachings on the Diné way of life.

Finally, students will scale their model up on paper and create a bill of materials for a full-size portable livestock corral.

Next Steps

Following the curriculum pilot, the curriculum will be improved and additional curriculum modules added to continue building out a robust culturally-relevant engineering design curriculum.

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References

Achieve. (2013, July 21). Retrieved July 21, 2013, from http://www.nextgenscience.org/next-generation-science-standards

American Indian Higher Education Consortium. (2011). *Living Science: Strengthening and Sharing Native Knowledge at TCUs*.

American Indian Higher Education Consortium. (2012). *AIHEC AIMS Fact Book 2009-2010*.

Aronilth, W. (1992). *Foundation of Navajo culture*. Tsaile, AZ: Navajo Community College.

Bassett-Jones, N. (2005). The paradox of diversity management, creativity and innovation. *Creativity and Innovation Management*, *14*(2), 169–175.

Blue, S. (2012). TMCC and NSF help students succeed. *Tribal College*, *24*(1), 35,38.

Cowan, F. M. (1995). *Exclusion of diversity and creativity impedes scientific innovation*. Scientist Inc.

Cox, T. (1994). *Cultural diversity in organizations: Theory, research and practice*. Berrett-Koehler Store.

Cunningham, C. M., & Hester, K. (2007). Engineering is elementary: An engineering and technology curriculum for children. In *Proceedings of the American Society for Engineering Education Annual Conference & Exposition, Honolulu, HI*.

Davis, C.-S. G., & Finelli, C. J. (2007). Diversity and retention in engineering. *New Directions for Teaching and Learning*, *2007*(111), 63–71.

Galvin, P., Hopkins, T., & White, K. (2005). *Navajo Nation Rural Systemic Initiative 1998 to 2005 Final External Evaluation Report* (Final External Evaluation Report No. ESI 9813616).

Jackson, S. E. (1992). Consequences of group composition for the interpersonal dynamics of strategic issue processing. *Advances in Strategic Management*, *8*(3), 345–382.

Johansson, F. (2006). *Medici Effect: What you can learn from elephants and epidemics*. Boston, MA: Harvard Business School Press.

McLeod, P. L., Lobel, S. A., & Cox, T. H. (1996). Ethnic diversity and creativity in small groups. *Small Group Research*, *27*(2), 248–264.

National Academy of Engineers. (2006). *Engineering studies at tribal colleges and universities*. Washington, D.C.: National Academies Press.

National Science Foundation. (2013a). Tribal Colleges and Universities Program (TCUP). Retrieved July 22, 2013, from

National Science Foundation. (2013b). *Women, minorities, and persons with disabilities in science and engineering* (No. 13–304).

Perry, W., Broers, A., El-Baz, F., Harris, W., Healy, B., & Hillis, W. D. (2008). Grand challenges for engineering. *National Academy of Engineering, Washington, DC*.

Pintrich, P. R., & Zusho, A. (2007). Student motivation and self-regulated learning in the college classroom. In *The scholarship of teaching and learning in higher education: An evidence-based perspective* (pp. 731–810). Springer.

Tobias, S. (1990, July). They're Not Dumb. They're Different. *Change*, *22*(4), 11.

Watson, W. E., Kumar, K., & Michaelsen, L. K. (1993). Cultural diversity's impact on interaction process and performance: Comparing homogeneous and diverse task groups. *Academy of Management Journal*, *36*(3), 590–602.

White, K., & Galvin, P. (2002). The Native American Test Score Achievement Gap and the National Science Foundation's Rural Systemic Reform. In *Proceedings of the 2002 American Educational Research Association Annual Meeting*. New Orleans.

Wigfield, A., & Eccles, J. S. (2000). Expectancy–value theory of achievement motivation. *Contemporary Educational Psychology*, *25*(1), 68–81.