CAREER: Engineering Design Across Navajo Culture, Community, and Society

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Dr. Jordan also founded and led teams to two collegiate National Rube Goldberg Machine Contest championships, and has 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 has appeared on many TV shows (including Modern Marvels on The History Channel and Jimmy Kimmel Live on ABC) and a movie with his Rube Goldberg machines, 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.
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Abstract

This paper presents integrated research and education methods for exploring how to engage and evaluate Navajo students in culturally-contextualized engineering design curricula. Under the theoretical frameworks of social constructivism and culturally relevant pedagogy, this study proposes to: (1) explore the ways in which Navajo students and Navajo professionals experience and understand engineering design in the context of their culture, community, and society through a phenomenographic approach; (2) conduct a design-based research study on the development of culturally-contextualized theory of learning and curriculum modules that will be piloted in several schools in the Navajo Nation; and (3) create and pilot tools to evaluate Navajo students’ experience of engineering design. The primary research questions are: (RQ1) What are the ways in which Navajo students and Navajo professionals experience, understand, and apply engineering design in the context of their culture, community, and society? and (RQ2) How do culturally-contextualized curricula affect the experience and understanding of engineering design, sense of cultural identity, and cultural attitudes of Navajo students?
Introduction

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

Over the last three years, I have worked with the Navajo Nation to bring an engineering design outreach program to middle and high school students on the Navajo Nation. Storytelling was embedded in the program to connect with students’ cultural experiences, but additional connections were sought. 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, and an engineering design process (ask, imagine, plan, create, improve).

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. 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.” This is echoed in creativity and diversity literature, which espouses that working in diverse groups increases the range of potential solutions. 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.” From 2000 to 2009, 0.6% of undergraduate students enrolled in undergraduate engineering programs were Native American. Tribal Colleges and Universities (TCUs) have increased the number of STEM-related degree programs available to Native American students in North America, but only 7% of students enrolled in TCUs were pursuing STEM degrees in 2009 – 2010. NSF initiated the Tribal College & Universities Program in 2001 to promote improvement in STEM education programs at Tribal Colleges and Universities. TCUP has supported a number of STEM education initiatives to improve curricula (e.g.,), 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. 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.” Students respond more positively to science if it is linked to society, and
research shows that if students perceive usefulness they are more motivated to persist in STEM fields. 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 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 will be adopting the Next Generation Science Standards in the near future, making this study both timely and necessary to understanding how to teach engineering design in a culturally relevant way.

Opportunity for Impact

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.

The following integrated research and education activities will support this mission:

1) Qualitative study to explore the ways in which Navajo students and Navajo professionals experience and understand engineering design in the context of their culture, community, and society
2) Design-based research study on the development of culturally-contextualized theory of learning and curriculum modules that will be piloted in several schools over 4 years in the Navajo Nation. These modules will be embedded into an existing engineering design program
3) Create and pilot tools to evaluate Navajo students’ experience of engineering design in the context of Navajo culture

Research Design

This research is guided by the following research questions and research design. Our constructivist grounded theory research questions are:

RQ1. What are the ways in which Navajo students and Navajo professionals experience, understand, and apply engineering design in the context of their culture, community, and society?

RQ2. How do culturally-contextualized curricula affect the experience and understanding of engineering design, sense of cultural identity, and cultural attitudes of Navajo students?

The research design was informed by Crotty’s four elements of a research study (epistemology, theoretical perspective, methodology, and methods). The elements of Crotty are particularly salient for this rigorous research design because they inform each other; epistemology informs theoretical perspective that informs methodology that informs the
selection of methods. Table 1 describes the four elements, specific theories and methods selected for this study and the rationale.

This study will use (Phase 1) a phenomenographic approach in year 1 to explore the ways that Navajo students and Navajo professionals experience engineering design in the context of their culture, and (Phase 2) a design-based research approach in years 2 - 5 to apply the results from the phenomenography to the iterative development of culturally-contextualized engineering curricula and theory.

**Phenomenography**

Phenomenography is a qualitative research method used for mapping out the different ways that people within a group understand and experience phenomena. For example, novices and experts in a particular field may experience and understand problems differently. According to Marton, it is used “for mapping the qualitatively different ways in which people experience, conceptualize, perceive, and understand various aspects of, and phenomena in, the world around them.” Experiences and phenomena are perceived differently by each individual, so phenomenography seeks to describe the “collective human experience of phenomena holistically.” Based in variation theory, phenomenographic studies result in the key components that comprise the variation under investigation. These categories of description “contain a variety of conceptions and thus indicate that there are differences in the ways a phenomenon is understood” and may be depicted as a taxonomy or hierarchy of understanding. The categories of description do not represent the individual responses from participants, but instead collectively reflect the understandings among a group of participants. Combining the categories of description with the relationships among the categories creates the outcome space of the phenomenography.

RQ1 explores how Navajo students and Navajo professionals experience, understand, and apply engineering design in the context of their culture, community, and society. Existing literature does not provide insight into engineering design in the context of Navajo culture, yet professionals exist who have integrated engineering design and Navajo culture together in a variety of ways. Since there are Navajo professionals engaging in engineering design in the context of their culture and we need to understand these phenomena in order to encourage Navajo students to become engineers, phenomenography is an appropriate choice to study and create an outcome space of ways to experience engineering design in Navajo culture. The resultant outcome space can be used to inform the study of the development of culturally-contextualized curricula in Phase 2 of this study, in addition to the development of tools to assess the outcomes.
### Table 1: Elements of a research study

<table>
<thead>
<tr>
<th>Epistemology</th>
<th>Definition</th>
<th>Selected</th>
<th>Rationale</th>
</tr>
</thead>
<tbody>
<tr>
<td>informs:</td>
<td>Theory of knowledge</td>
<td>Constructivism</td>
<td>To understand how Navajo students and Navajo professionals learn engineering design in the context of their culture</td>
</tr>
<tr>
<td>Theoretical Perspective</td>
<td>Philosophy that informs methodology</td>
<td>Social Constructivism</td>
<td>To understand how Navajo students and Navajo professionals create meaning through engineering design in their culture</td>
</tr>
<tr>
<td>Methodology</td>
<td>Design connecting methods to outcomes</td>
<td>Phase 1 / RQ1: Phenomenography</td>
<td>Little is known about how Navajo students and Navajo professionals experience and understand engineering design in the context of their culture, and how this knowledge can inform culturally-contextualized curriculum design</td>
</tr>
<tr>
<td>Methods</td>
<td>Implementation of methodology</td>
<td>Phase 1 / RQ1: Phenomenography</td>
<td>D1. To screen potential participants</td>
</tr>
<tr>
<td></td>
<td>D2. Phenomenographic interviews</td>
<td>Phase 2 / RQ2: Design-Based Research</td>
<td>D2. To understand participants’ experience</td>
</tr>
<tr>
<td></td>
<td>D3. Content assessments</td>
<td>D3 – D7. To understand and triangulate students’ experience of a culturally-contextualized curriculum</td>
<td></td>
</tr>
<tr>
<td></td>
<td>D4. Artifact elicitation interviews</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>D5. Navajo culture assessments</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>D6. Documents and design artifacts</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>D7. Direct observation, field notes, and reflections</td>
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<td></td>
</tr>
</tbody>
</table>

Phenomenography came out of work in Sweden in the 1970s, and has been used in a number of education-related studies in the last 40 years. For example in engineering education, Daly et al. used phenomenography to describe the experience of design across professionals from a number of fields. Phenomenography has also been used in higher education to study ways of experiencing human-centered design, sustainable design, cross-disciplinary practice in engineering contexts, the intended learning outcomes of instructors using computational simulations in the classroom, learning to program, and program design for teachers in higher education. Phenomenography has also been used to study K-12 education, including conceptions of matter and understanding the concept of the mole in chemistry. Phenomenography has also been used as part of curriculum and program assessment, including
with faculty development programs for teaching and reflection to shape faculty teaching approaches.

**Design-Based Research**

According to the Design-Based Research Collective, “design-based research is an emerging paradigm for the study of learning in context through the systematic design and study of instructional strategies and tools.” Based on the idea of design experiments developed by Brown and Collins, design-based research is more than a process to tweak curricula. According to Cobb et al., “the purpose of design experimentation is to develop a class of theories about both the process of learning and the means that are designed to support the learning.” By creating rich theories of learning, design-based research can provide a foundation to “create and extend knowledge about developing, enacting, and sustaining innovative learning environments.” These theories are designed alongside curricula and reported with “rich descriptions of context, guiding and emerging theory, design features of the intervention, and the impact of these features on participation and learning.”

RQ2 explores how culturally-contextualized curricula affect the experience and understanding of engineering design, sense of cultural identity, and cultural attitudes of Navajo students. Cultural infusion into curricula is part of the Navajo plan for school improvement, and resulted in improved performance in math. The purpose of Phase 2 of this study is to draw from the ways of experiencing engineering design in the context of Navajo culture identified in Phase 1 and develop a model of the process by which students develop a deeper understanding of their culture and how it connects with engineering design, in addition to the types of tasks and teacher practices that can support this learning. This aligns with a core strength of design-based research: “designing theories of learning and instruction that are contextually based.” In addition, it is particularly appropriate for research on engineering education due to its data-driven and iteration-based design process, which is not unlike the engineering design process under study for cultural contextualization.

Design-based research has been used in a number of studies in K-12 over the last 20 years, including in engineering education, virtual learning environments, interactive multimedia and web-based learning modules, technology support for gifted children, and mathematical development. There has also been significant design-based research work done in physics education.

**Research Methods**

This study will be conducted in two parts: Phase 1 will use phenomenography to explore RQ1, which will inform Phase 2’s design-based research focus on RQ2.

**Phase 1 / RQ1: Phenomenography (Year 1)**

Phase 1 of this study will be focused on research on practice to understand the ways in which Navajo students and Navajo professionals experience engineering design in the context of their culture. Phase 1 (see process, Figure 1) will begin with administering a participant screening...
questionnaire to potential participants with the goal of understanding their backgrounds and experiences. This will facilitate maximum variation sampling \(^6^0\), with the goal of having participants with diverse experiences of engineering design. Semi-structured 1-hour phenomenographic interviews will be conducted to explore participants’ understandings of the phenomena under study \(^2^9, ^3^1, ^6^1\), in this case engineering design in the Navajo context. Interview data will be analyzed in an iterative process of sorting, generating descriptions, and collaborating \(^3^4, ^4^6, ^4^7\) and Daly \(^3^3, ^4^0\). Once iterations in the analysis have ceased, the final categories and relationships among them will be reported and used as a foundation for Phase 2 of the study.

\[\begin{array}{c}
\text{screening} & \rightarrow & \text{maximum} & \rightarrow & \text{interviews} & \rightarrow & \text{analysis} & \rightarrow & \text{preliminary} & \rightarrow & \text{final} \\
\text{questionnaire} & & \text{variation} & & \text{phenomenographic} & & \text{phenomenographic} & & \text{outcomes} & & \text{outcomes}
\end{array}\]

*Figure 1: Phase 1 research process*

**Phase 1: Population and Sampling**

The Phase 1 sampling procedure focused on finding a diverse group of Navajo students and Navajo professionals with exposure to engineering design in order to understand how engineering design intersects with Navajo culture. The Navajo Nation’s Office of Diné Science, Math, and Technology will provide access to a pool of Navajo students and Navajo professionals who have or are willing to learn about engineering. I will work also work with the American Indian Science and Engineering Society (AISES) to identify additional Navajo engineering professionals to recruit for the study.

With potential participants identified, selection of participants was guided by the maximum variation sampling strategy \(^6^0\). Participants were selected to maximize variation based on specific criteria, which are listed in Table 2. These criteria were selected to maximize the traditional versus non-traditional cultural paths of participants, which potentially will have an impact on the ways that they experience engineering design. The sampling goal will be approximately 25 participants in total (approximately half students, half professionals), which is appropriate and typical for phenomenographic studies \(^6^2\) because most studies “depend on statistical methods of generalization to understand the experiences of underrepresented people, despite the fact that the number of such people are usually too low to make analysis of them statistically significant” \(^6^3\). This sampling strategy is appropriate to support a phenomenographic investigation, whereas representative sampling may not provide a complete picture of the different ways people experience engineering design in the context of Navajo culture.
Table 2: Factors for maximum variation sampling (N = 25)

<table>
<thead>
<tr>
<th>Students in Grades 6 - 12</th>
<th>Professionals</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Raised on/off Navajo Nation</td>
<td>- Raised on/off Navajo Nation</td>
</tr>
<tr>
<td>- School on/off Navajo Nation</td>
<td>- Work on/off Navajo Nation</td>
</tr>
<tr>
<td>- Grade level</td>
<td>- Years of engineering experience</td>
</tr>
<tr>
<td>- Gender</td>
<td>- Discipline</td>
</tr>
<tr>
<td></td>
<td>- Gender</td>
</tr>
</tbody>
</table>

Sampling Navajo students across middle and high school, and sampling Navajo professionals at various stages of their careers will provide depth to see the breadth of experiences of engineering design in the context of Navajo culture.

Phase 1: Data Collection

D1. Screening/Background Questionnaires

Potential participants will be asked to complete a short paper-based or online screening questionnaire, and the results will be collected in a database. The questionnaire will consist of multiple choice and short answer questions that check for the factors described in Table 2. Results from the questionnaire will be used to select initial participants using the maximum variation sampling strategy described above, and also used to contextualize the phenomenographic interview questions.

D2. Phenomenographic Interviews

Semi-structured phenomenographic interviews will be situated in discussions of participants’ experiences to explore their understandings of phenomena under study. The interview protocol will consist of questions (see examples, Table 3) designed to encourage participants to discuss engineering design in the context of their culture. Interviews will be conducted via videoconference, phone, or in person.

Phase 1: Data Analysis

The analysis of the phenomenographic data will be based on that of prior work by advisory board members Light and Daly. The unit of analysis will be each individual interview to reflect the holistic nature of RQ1. The process will be as follows: (1) Two researchers will read and reread the transcripts and discuss the themes emerging from the data; (2) Interviews will be sorted into groups based on emergent themes; (3) Each group of interviews will be re-read by one researcher; (4) Detailed descriptions will be written of how participants experience engineering design in each group of interviews, relying heavily on direct quotations to provide rich, thick description; (5) Relationships between each group of interviews will be described and an emergent hierarchy or taxonomy defined; (6) Two researchers will review the original transcripts and challenge the categories and hierarchy; (7) An outcome space (including categories of description and relationships among them) will be finalized and reported. This
process is highly iterative and will repeat until the categories and descriptions fully capture the groupings. The results from this part of the study will inform Phase 2 (described below), a design-based research study to develop a theory of culturally-contextualized engineering design curricula.

*Table 3: Sample phenomenographic interview questions (based on Daly et al. 33)*

<table>
<thead>
<tr>
<th>Section</th>
<th>Sample Questions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Background</td>
<td>Can you tell me about your work as someone with an engineering background?</td>
</tr>
<tr>
<td>Describing</td>
<td>Can you tell me about an experience you have had doing engineering design?</td>
</tr>
<tr>
<td>Experiences</td>
<td>How did you approach the task from beginning to where it is now?</td>
</tr>
<tr>
<td>Comparing</td>
<td>Can you tell me about an experience you have had doing engineering design</td>
</tr>
<tr>
<td>Experiences</td>
<td>within your culture, community, or society?</td>
</tr>
<tr>
<td>Design Lens</td>
<td>How does engineering design relate to your culture, community, and society?</td>
</tr>
</tbody>
</table>

*Phase 2 / RQ2: Design-based Research (Years 2-5)*

Phase 2 of this study will be focused on taking research to practice from phase 1 to inform the design of culturally-contextualized curriculum modules, while doing research on practice on the development of theory, curricula, and assessments for the classroom. Years 2 – 5 also represent the core of the education plan, supporting culturally-contextualized curricula and camp interventions for students. Year 1 will end with teacher recruitment, and year 2 (see process, Figure 2) will begin with a curriculum stakeholder meeting to make key decisions on the learning outcomes, content, context, and assessment of (3) new culturally-contextualized curriculum modules for 6th, 7th, and 8th grade classrooms. These modules will be embedded into an existing engineering program in the summer of year 2, and data described below will be collected and analyzed. The curricula and assessments will be revised, and at the beginning of year 3 the curriculum modules will be tested in the classroom with (3) classes of (25) 6th, 7th, and 8th grade students and tested again in (3) 1-week summer camps. Data will be collected on all participants in the classes, and a subset of 5 students from each class will be interviewed using artifact elicitation (based on the photo elicitation interview technique 66). Data will be analyzed and triangulated with existing theory, an initial theory of culturally-contextualized curricula for Navajo students developed, and the curricula and assessments revised. Years 4 and 5 will repeat the process from year 3, resulting in finalized and triangulated theory, curriculum, and assessments by the end of year 5.
Phase 2: Population and Sampling

The Phase 2 sampling procedure will focus on 6th – 8th grade Navajo students who will be exposed to the engineering design process as part of culturally-contextualized curricula used in both in-school and summer programs on the Navajo Nation. The Navajo Nation’s Office of Diné Science, Math, and Technology, Navajo Nation Department of Diné Education will provide access to a pool of Navajo students, teachers, and schools to participate in this part of the study.

In order to answer RQ2, a stratified purposeful sampling strategy will be used to select participants to equally represent 6th, 7th, and 8th grade students (see Table 4). This sampling strategy is appropriate to be able to compare how Navajo students in different grade levels experience engineering design and respond to culturally-contextualized curricula. Each participant will receive a $10 incentive for his/her time in year 2, and $20 for his/her time in years 3 – 5.

Table 4: Strategy for stratified purposeful sampling (N = 250)

<table>
<thead>
<tr>
<th></th>
<th>Year 2 (pilot)</th>
<th>Year 3</th>
<th>Year 4</th>
<th>Year 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>6th grade</td>
<td>8</td>
<td>25</td>
<td>25</td>
<td>25</td>
</tr>
<tr>
<td>7th grade</td>
<td>8</td>
<td>25</td>
<td>25</td>
<td>25</td>
</tr>
<tr>
<td>8th grade</td>
<td>9</td>
<td>25</td>
<td>25</td>
<td>25</td>
</tr>
</tbody>
</table>

Phase 2: Data Collection

Design-based research studies rely heavily on assessment and research instruments to provide data for feedback to both the theory and curriculum under development. Assessments developed and used during the study must assess content, culture, and the intersection between content and culture.
D3. Content assessments

Over the duration of Phase 2 of this study, content assessments appropriate to the culturally-contextualized curriculum modules designed during the curriculum stakeholder meeting in year 2 will be developed, piloted, and refined over years 2 – 5 of the study. Science standards will be referenced (e.g., Arizona Academic Content Standards for Science and Next Generation Science Standards) and existing assessments will be used or adapted (e.g., the American Association for the Advancement of Science Assessment Website). Some assessments may be given both before and after the intervention.

D4. Artifact elicitation interviews

A semi-structured artifact elicitation interview will be conducted in person during interventions to explore how students experience engineering design and the content modules in the context of culturally-contextualized curricula. The 15-minute interviews will rely on a physical artifact/creation that the participants created as part of the engineering program, and begin with asking him or her to describe the artifact. Further questions (see Table 5) will also rely on references to the artifact to elicit “thick description,” and questions will evolve based on emergent themes discovered during the experiment.

Artifact elicitation interviews extend the qualitative inquiry approach of photo elicitation, where interviews that rely on photos “evoke information, feelings, and memories that are due to the photograph’s particular form of representation” and stimulate “latent memory, reducing areas of misunderstanding, eliciting longer and more comprehensive accounts of ideas... eliciting values and beliefs, and connecting to core definitions of the self to society, culture, and history.” In addition, the photo elicitation method has been used successfully in engineering education, science, and math as both a research and pedagogical method. Engineering design artifacts created by participants in the engineering program are similar to photos in the sense that they embody the understanding by Navajo students of engineering design in the context of culture, making artifact elicitation an appropriate choice to support the investigation of RQ2.

D5. Navajo culture assessments

Over the duration of Phase 2 of this study, assessments of student learning and experience of Navajo culture will be developed, piloted, and refined over years 2 – 5 of the study. Some assessments may be given both before and after the intervention. The Diné Culture Standards for middle school students adopted in June 2013 will be referenced, and the Navajo Cultural Identity Measure (NCIM) developed by the director of the Navajo Nation’s Office of Diné Science, Math, and Technology will also provide support in cultural assessment.

D6. Documents and design artifacts

Documents and design artifacts created by participants during the intervention and teachers in support of the intervention will be collected to support analysis of the effectiveness of the intervention and development of theory.
Table 5: Sample artifact elicitation interview questions

<table>
<thead>
<tr>
<th>Sample Questions</th>
<th>Assessment Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>What did you have to learn to build [project]?</td>
<td>Content</td>
</tr>
<tr>
<td>How does your experience of engineering design relate to your culture?</td>
<td>Content + Culture</td>
</tr>
<tr>
<td>What did you learn about your culture by doing this project?</td>
<td>Culture</td>
</tr>
</tbody>
</table>

D7. Direct observation, field notes, and reflections

In addition to data sources D3 – D6, direct observation, field notes, and reflections by teachers and research staff will be used to triangulate findings and facilitate improvements to the theory and curricula. According to Cobb et al. 48, “the research team deepens its understanding of the phenomena under investigation while the experiment is in progress. It is therefore important that the team generates a comprehensive record of the ongoing design process.”

Phase 2: Data Analysis

In the summer of year 2, (3) curriculum modules (one 6th, one 7th, and one 8th) will be piloted and data collected. Interviews will be transcribed and the data analyzed, triangulated, and compared with the theoretical frameworks in Table 6. Additional theoretical frameworks will be enlisted as themes emerge within the data. Based on these findings, revised versions of the curriculum modules and assessments will be created. These modules will be tested in the classroom at the beginning of years 3, 4, and 5, where each year data will be collected, analyzed, triangulated, and a theory of culturally-contextualized curriculum for engineering developed and revised. These data will be used to refine the next iteration of the curriculum and assessments will be revised, and the analysis process will be repeated until finalized in year 5. By triangulating findings from multiple data sources, “reliability of findings and measures can be promoted” 37. Comparisons between assessed experiences of engineering design in the context of culture will be compared with the outcome space generated in phase 1 of this study, and the categories refined.

Table 6: Theoretical frameworks to inform analysis

<table>
<thead>
<tr>
<th>Conceptual Framework</th>
<th>Relevance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bloom’s Revised Taxonomy 78, 79</td>
<td>$RQ2$: comparison of engineering design learning trajectory with theories of learning</td>
</tr>
<tr>
<td>Culturally Relevant Pedagogy 80</td>
<td>$RQ2$: development of culturally-contextualized curricula</td>
</tr>
</tbody>
</table>

Expected Results: Theory, Curriculum, and Assessments

The theory of learning developed in Phase 2 of this study will provide insight into culturally-contextualized engineering design curricula and assessment tools for Navajo middle school students, grounded in the Phase 1 study of how Navajo Students and Navajo professionals
experience, understand, and apply engineering design in the context of their culture, community, and society. This theory will provide deeper understanding of the learning ecology, which is “a complex, interacting system involving multiple elements of different types of levels... by anticipating how these elements function together to support learning” 48, of engineering design in Navajo culture. Elements include the culturally-contextualized curricula developed in Phase 2 of this study, the inquiry-based discourse with which to learn engineering design, assessment tools, and “the practical means by which classroom teachers can orchestrate relations among these elements” 48. The process by which this theory will be developed is transferrable to other cultures. This work will provide a foundation for future work in understanding how Navajo students learn design at different ages, and validation of assessment instruments.

Acknowledgements

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References

1 Aronilth, Wilson (1992) Foundation of Navajo culture, Tsaile, AZ, Navajo Community College.


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


Vygotsky, Lev (1978) Mind in society: The development of higher psychological processes,


Pawley, Alice (2013) ‘“Learning from small numbers” of underrepresented students’ stories: Discussing a method to learn about institutional structure through narrative’, in Proceedings of the American Society for Engineering Education (ASEE) Annual Conference & Exposition, Atlanta, GA.


