A Philosophy of Learning Engineering and a Native American Philosophy of Learning; An Analysis for Congruency

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Strengthening Pathways to Engineering; Introducing the Navajo Voice in Engineering Design
Abstract

Engineering needs diversity so that creative solutions may be developed for the modern-day grand challenges. Native Americans can offer a unique perspective to solving problems due to their worldview, yet they remain drastically underrepresented in engineering and broader STEM fields. Restricting the pathways to engineering, K-12 students in non-mainstream groups can experience alienation from science and engineering due to the universalist view in which K-12 science is taught. However, engineering education can support alternative ways of knowing through curriculum that is culturally responsive. Culturally-responsive schooling is to design learning environments and train educators with appropriate curriculum, pedagogy, standards, and assessments that will value and foster a student’s cultural identity. This study deconstructs a traditional Navajo philosophy of learning and predominant philosophies of learning in engineering design to make explicit the differences between ways of knowing. The outcome of this study is an evaluation of how an engineering education might fit into a traditional Navajo worldview. The intent of the work is to contribute to the conversation of how culturally-responsive schooling may be designed to minimize barriers to engineering for Native American students.

Introduction

The National Research Council has released the Next Generation Science Standards for K-12 education. For the first time, engineering is represented in K-12 standards. The intent of this shift is to better prepare young students to pursue pathways in science, engineering, technology, and mathematics. With this change comes the responsibility to design a learning progression of engineering content that fits within science curricula. Posing a challenge, science curricula are typically designed from the views of Western modern science. This represents a limited perspective of science teaching because it adheres to a universalist model and does not incorporate alternative ways of knowing the world, which can originate from the cultural perspectives and philosophies of learning of non-dominant groups. Compounded with outsider teachers coming into communities unfamiliar to them and having limited experience with the community’s ways of knowing, science curricula and its support materials struggle to validate and strengthen a community’s ways of knowing. This deficit view of non-universalist science may alienate populations of students who hold alternative ways of knowing the world that develop from their cultural perspective.

Many of the students with alternative ways of knowing the world include minorities that STEM education seeks to attract. Supporting Native American students in their pathways to STEM careers is of particular interest to the engineering and engineering education communities. The National Science Foundation-American Indian Higher Education Consortium (p. 3) writes: 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.
The National Academy of Engineering echoes this by stating that the “engineering profession needs the perspectives of American Indians… and reservations need the culturally relevant contributions of American Indian engineers”.

If STEM education is to be successful in supporting Native American students in pathways to STEM careers, the students should not be expected to separate their learning from their culture. Learning is a cultural process that involves cognitive factors including identity and affect. Furthermore, cognitive psychology literature informs us that students need to see personal relevance in the content in order to value the learning of that content. If the science and engineering content is forcibly divided from the student’s identity, including their culture, then it is difficult for students to form value for learning the content.

Science and engineering curricula should support students in upholding their ways of knowing science and engineering through culturally contextualized curricula. The development of culturally contextualized curricula involves understanding a community’s ways of knowing, including the logic, reasoning, and philosophies of learning that may contribute to understanding scientific and engineering knowledge and practices.

Research Questions and Study Overview

This study is guided by the following research questions: What is the traditional Navajo philosophy of learning? How does a philosophy of learning engineering design fit within the traditional Navajo worldview?

The intent of these research questions is to begin to consider how Navajo students may be supported in learning engineering through curricula that is contextualized to a Navajo philosophy of learning, logic, and reasoning. This study addresses these research questions by conceptualizing the traditional Navajo philosophy of learning used to direct and formulate pedagogy in K-12 and higher education on the Navajo Nation. To explicate such information, the authors relied upon documentation and empirical work published by Navajo scholars and educators as well as on education documentation by and for Navajo schools. One of the authors also took an on-site Navajo culture course at a Navajo higher education school, where the traditional Navajo philosophy of learning guided the curriculum and its support pedagogy. A conceptual framework, whereby the Native voice takes center-stage and is not rejected when it fails to support engineering learning, was used to guide the analysis in this study and is presented in the next section. This work is intended to contribute to the conversation about culturally-responsive engineering education for Navajo students.

Using a “Cultural Bridge of Understanding” Approach

A conceptual framework comprised of three dimensions of reality (Native reality, White reality, and Native-White relations) will be used to position the approach for analysis in this study. Developed primarily for historical documenting and analysis, each of the three dimensions represents a different way of understanding the world and a different approach for analyzing phenomena (e.g. learning of engineering). See Figure 1 for a diagram of this framework. The first dimension represents the mainstream, White way of knowing the world. When analyzing phenomena, the first dimension represents looking onto Indians and matters that concern them with disregard to the Native ways of seeing. The second dimension is one where the Indian and mainstream perspectives collide and represents the majority of analysis. It is through the second
dimension that a bridge to understand the third dimension - Native reality - takes place. The third dimension represents the Native ethos (See Figure 2 for a conceptual map illustrating main ideas from a model for an Native American viewpoint). This framework was developed so that mainstream academics could begin to “‘see’ things from the Native perspective of a tribal community’s inside”, rather than viewing cultural values as wavering or something to be rejected when it does not fit into the White reality. The framework recognizes that variations of ethos across tribes and people exist and calls upon these variations within the third dimension to develop a strong Native foundation in the academic literature.

Figure 1. Three Dimensions, A Conceptual Framework for Understanding

The three-dimensional conceptual framework is useful for educational initiatives aimed for nonmainstream groups because it provides a model to construct curricula and support materials that are contextualized to the Native point of view. The analysis conducted for this study moves out of the first dimension (where the Native point of view is examined from a White, mainstream lens) and uses the second dimension as a cultural bridge to understanding the shared experiences between Navajo reality and the reality represented in engineering. To move from the first to the second dimension, the Navajo philosophy of learning was analyzed to understand Navajo thought, logic, and decision-making. Predominant philosophies of learning engineering design were then analyzed for its fit to the Navajo philosophy. Areas of discontinuity are highlighted as cautionary points and represents areas of engineering curricula that must be revised to support the learning of engineering from a Navajo view.
A Navajo Framework for Learning

The origin for a Navajo perspective comes from the generations of oral tradition and sacred knowledge contained within the Navajo stories, myths, and legends. The cultural values and ways of seeing and interpreting the world are explained in these oral histories and define Navajo reality, logic, and reasoning. Navajo scholars looked to the Navajo worldview, situated in sacred knowledge and held by the elders of the tribe, to explicate a framework for learning that would support Navajo students in learning Navajo and Western knowledge from the third dimension, or a Navajo view. The result was the Dine Philosophy of Learning, now the Diné Educational Philosophy. The Navajo framework for learning is intended to provide an understanding for the lay Navajo of their identity as a Navajo, their Navajo objectives in life, and the ancient system for organization of knowledge within an educational context. This roadmap for learning from the Navajo view justifies how decisions are made according to Navajo logic.

The next section is an overview of the elements that define Navajo reality and Navajo cultural values and that are represented in the Navajo framework for learning. The section begins with the Navajo purpose, followed by an explanation of how knowledge should be converged and internalized, and links to Western knowledge. The Navajo framework for learning has
framed the mission and vision of the Navajo tribal colleges, the Diné College and Navajo Technical College. The Diné College, in particular, has historical and present-day significance to Navajo self-determination. The Diné College began a tribal college movement and remains a thriving institution that models how to support its people in higher education through a Navajo cultural framework for learning and teaching. The Department of Diné Education for preK-12 has also developed and adopted a Navajo framework for learning based upon the groundwork by Navajo scholars and the tribal colleges. The presence of a Navajo framework for learning in the Navajo educational system provides a critical starting point to develop engineering curricula from the Navajo view.

The Navajo Purpose

The Navajo purpose is to reach hózhó - a state of peace, happiness, and plenty where balance and harmony can be achieved, and to learn behavior applicable to hózhó. This is referred to as the “Beauty Way of Life” or the beautiful life, hózhóogo iina. Hózhó represents the world of the diyin diné - the Holy People, who were formed from the omniscient and omnipotent Holy Wind and created the Earth and its elements, including the Earth people, alongside the Holy Wind. The sacred teachings inform the people that they have unlimited potential, even to the extent of becoming Holy People which represents harmony and balance. This purpose frames the Navajo motives for learning and provides justification for the Navajo ethos of “seeing.” To achieve the Navajo purpose, the stories tell the people to look to the knowledge provided by the creators - the Holy Wind and the Holy People - that is within the elements of the Earth, parts of the day, and placed in the four cosmic directions. Knowledge is found in all physical and metaphysical elements, and therefore should be respected, as they are a part of the “Natural Democracy.”

The Four Directions

Within the Navajo creation story, the creators provided the Navajo people with guides for direction and rest in the form of four colored lights: dawn - hayoolkáál, blue twilight - nihodoottlizh, evening twilight – nihootsooi, and darkness – chahalheel. The guides were placed in the four directions, with dawn being in the east, blue twilight in the south, evening twilight in the west, and darkness in the north. The elements of the Earth were also placed in the four directions, with light being in the east, water in the south, wind in the west, and black wind in the north. Mother Earth and Father Sky – the spirits who emerged from the lights and the winds – then placed knowledge for the peoples’ principles of living in the four directions. The knowledge within the four directions and the cyclical, directional nature of the Navajo way of seeing is critical to Navajo logic.

East. The east represents the knowledge that gives the people direction for living through the skills of thinking, awareness, and strength. According to Benally’s original documentation of the Diné Philosophy of Learning, “All knowledge that would prepare a person to make intelligent decisions whenever he must weigh values in order to determine a choice of behavior is found inherently in the east.” Character development is structured from knowledge found in the east and people are encouraged to discipline both the heart and mind.

South. The people are to look to the south for sustenance, which represents all knowledge that goes into making a living. The sacred knowledge found in prayers and teachings shows the importance of traveling to make a living and on the values of work ethic and
responsibility. Dignity can be found in this direction, for learning how to be responsible and be a contributing member of the community is vital to the survival of the people.

**West.** In the west, the knowledge required to allow families to gather and think, plan, and teach is found. In this direction, the focus is on k’é, which is a kinship term that represents the relationships with the family, community, and the natural environment as well as an acknowledgement of the inherent value in others. In this direction, the function of duality, or the endowments given to man and woman to function in the natural world, come into play.

**North.** The north embodies all knowledge of reverence and respect for nature. The Navajo way of life recognizes that all things in the world are intelligent and full of life and that gratitude and respect should be given to all things. Understanding that the world is highly ordered and that there is power in the natural order of things is fundamental to the knowledge of the north.

**Metaphysical Reality.** Understanding that metaphysical and physical realities are one is key to Navajo reality and purpose. Spirits have a critical role in the Navajo worldview, for they are endowed with responsibilities within the natural order of things. To protect the knowledge sources, the creators assigned each of the four cosmic directions with a wind spirit - blue, yellow, black, and white winds - to guard the knowledge found within the given direction.

The structure and functions of knowledge, found within all things, define the objectives of Navajo life and the ancient system of knowledge organization. The cyclical, directional nature of knowledge provides the architecture for a Navajo framework for learning. Table 1 represents a high-level overview of the knowledge and natural and spiritual components that can be found in each direction, which is the basis of the Navajo framework for learning.

<table>
<thead>
<tr>
<th>Direction</th>
<th>Principle for Living</th>
<th>Skills/ Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>East</td>
<td>Direction for living</td>
<td>Thinking, awareness, strength</td>
</tr>
<tr>
<td>South</td>
<td>Sustenance</td>
<td>Work ethic, responsibility, contribution to the community</td>
</tr>
<tr>
<td>West</td>
<td>K’é (kinship)</td>
<td>Relationships with the family, community, and natural environment; Families gathering, planning, thinking, and teaching</td>
</tr>
<tr>
<td>North</td>
<td>Rest and respectfulness</td>
<td>Respect for nature, gratitude</td>
</tr>
</tbody>
</table>

**Converging and Internalizing the Knowledge**

The internalization and convergence of all knowledge is key to finding balance in life and reaching hózhó. A holistic approach to knowledge acquisition and learning is required to reach hózhó because it is a state of harmony where all knowledge converges. Holy People – who live in a state of hózhó – possess full knowledge and, as described above, guide the people through adopting the knowledge found in the elements of the Earth. In Navajo philosophy, all natural things possess consciousness and knowledge, and humans must access their thought relationships with these natural things to be harmonious. By converging all knowledge and internalizing it, a human is becoming aware of the circuitry of information in the natural world and flows of ideas and messages through those circuits, where the sum of the intelligence of all parts is greater than the individual parts. Achieving this requires accessing all parts of the self - emotional, spiritual, and physical - and becoming aware of the self’s integration with the complex, natural
world. This comes from the Navajo prayers and oral stories, which emphasize the need for spiritual, emotional, social, physical, and environmental health to live the beautiful life, hózhóogo iina. Benally writes of what happens when all knowledge is not drawn upon, “We become narrow in our views and cannot see the connection between all knowledge. We wind up perpetuating the imbalance within between ourselves, other people, and the natural world.” Disharmony in the world and distortions in the mind are attributed to the world’s problems.

Four Stages of Internalization of Knowledge

Navajo stories and prayers explain that in order to restore balance and achieve hózhó one must commit to the four stages of internalization of knowledge: nitsáhákees - thinking, nahat'á - planning, iiná – living or implementing, and sihasin – reflecting and assuring.

All of the stages should be performed when drawing upon knowledge from each of the four cardinal directions and should build on one another. This begins with knowledge becoming a part of the person’s thought, then becoming a committed part of the person’s thought schema and actions, then graduating to becoming the way to manage life in a meaningful way, and, finally, the knowledge, skills, and discipline will come together through contentment and be apparent in the person’s prayers, songs, and teachings. To this day, this four-stage model of knowledge internalization is present at the Navajo tribal colleges (Diné College and Navajo Technical College) and is used to fulfill the mission for learning from the third dimension. The cyclical nature of internationalization of knowledge is key to the Navajo way of seeing.

Links to Western Knowledge

With a framework that is “uniquely of Indian origin”, Benally identified ways in which Western curriculum and pedagogy could be integrated into the Native framework. This involved aligning coursework with each source of knowledge (e.g. language with the principles of the east, economics with the south, sociology with the west, and the natural sciences with the north) and explicitly exploring the spiritual and ethical values of each subject. To maintain the integrity of the Navajo worldview within the coursework, Benally writes that a holistic curriculum should connect the coursework to one another and emphasize all areas of development and growth – spiritual, emotional, physical, and environmental. He advocates that the teachings of Blessing Way and Protection Way should be a mainstay in the pedagogy in order to practice character development (e.g. integrity with social transactions) and learn new skills and knowledge (e.g. viewing coursework through a lens of ecological awareness). By providing Western links to a Navajo framework for learning, Benally attempted to represent a connection between Navajo and Western knowledge while explicating a framework from Navajo sacred knowledge. The intent of this was to prepare Navajo children to be able to function in the modern world while also having a firm understanding of what it means to be Navajo and the Navajo worldview that defines Navajo life. Benally stressed that mainstream educational goals must be evaluated to determine if they are what the community wants for the Navajo children. Benally writes:

The values inherent in Western society are often contrary to the teachings of our fathers. We must think about and reevaluate the goals of Western life to ascertain whether we desire its intrinsic values. If we question its objectives we must return to the values that are inherent in sa’ah naagháí bik’eh hózhó, which inspire the people to greater good.
The Navajo framework for learning is contextualized within sacred knowledge; learning cannot be separated from this spiritual part of life, for the purpose of learning from a Navajo perspective is “to gather knowledge that will draw one closer to a state of happiness, harmony, and balance”\(^1^2\).

Although the coursework found in the Navajo tribal colleges and preK-12 education is not organized according to the structure overviewed in this section, the purpose remains the same: to situate learning from a Navajo view. The Dine College’s 2013-2014 General Catalog lists their four main principles that uphold Navajo logic, including the convergence and internalization of knowledge:

- **Nitsáhákees.** Critical thinking. Baa nitsídizíkees. Apply the techniques of reasoning.


The purpose in overviewing these suggestions outlined by Benally\(^3\) is to show how a Navajo framework for learning should be the foundation for the development of engineering curricula and pedagogical strategies. Engineering curricula developers should rely upon the Navajo principles for thinking and knowing - nitsáhákees, nahat’á, iiná, and sihasilín - in their decision-making processes\(^6^1^3\).

**Summary: A Navajo Framework for Learning**

Educational work done by cultural education leaders, such as Herbert Benally, paved the way for students to learn in an environment that supports their Navajo identity, including their history, language, and culture through songs, ceremonies, and prayers. Benally’s\(^3\) Diné Philosophy of Learning transformed the way education was taught at the tribal college - the Diné College - by grounding learning in a Navajo framework where the Navajo purpose, sources of knowledge, and ways to converge and internalize knowledge were upheld. This then became an example for the Navajo Technical College and preK-12 education and set the mission for learning that is based in cultural knowledge and reality. For example, the Department of Diné Education has a preK-12 mission to “provide lifelong learning for the Navajo People and to ensure cultural integrity and sovereignty of the Navajo Nation”. The Department of Diné Education has developed cultural standards in the areas of character building, culture, history, language, and government that are uniquely Navajo. These standards represent a trajectory of learning for Navajo children to support the value of the Navajo identity and purpose. A Navajo framework for learning provides a conceptual framework for teaching and learning where Western knowledge and its subjects could be grounded in the Navajo worldview.

**A Philosophy of Learning Engineering and Engineering Design**

A philosophy of learning engineering is a set of beliefs and ideas about how the learning of engineering should take place. This includes what engineering content should be learned, how
engineering students should learn it, how the teacher should support the learning of engineering, and so on. The philosophy of learning engineering is informed by the philosophies of engineering and philosophies of education.

The philosophies of engineering (stemming from professional practice) and the philosophies of education (stemming from higher education models) have a history of negotiating with one another to inform how students should be prepared to be engineers

15. This negotiation matters because “viewing engineering as essentially design, or problem-solving, or applied science impacts educational methods”

14. At its inception in the 19th Century, engineering education was developed under the applied sciences, gaining an identity for engineering as an engineering science by the post World War II era. This began an academic tradition that still stands today where the bulk of engineering learning is through a traditional curriculum of theoretical mathematics and sciences with educators transmitting knowledge and using pedagogical strategies of presenting methods for structured, defined problems

16,17. As engineering practice demanded changes to be made, the curriculum was appended with time in the laboratory to enhance experiences with putting knowledge to practice, but maintained a focus on narrow, discipline-specific topics

16. Since the turn of the new millennium, there has been national-level discomfort that a traditional curriculum with a focus on technical problem-solving still overwhelms engineering education and has not prepared engineers to meet the needs of modern-day engineering

17,18. Sheri Sheppard and the Carnegie Foundation for Advanced Teaching

17 write, “Although engineering schools aim to prepare students for the profession, they are heavily influenced by academic traditions that do not always support the profession’s needs”. The engineering education community has responded to the new demands on engineering education by propelling the philosophy of learning engineering towards one that is more focused on the nature of work of professional engineers

1. While there is debate about what approximation of practice is most appropriate for an engineering education, many are in agreement that meaningful learning of engineering takes place through an inductive approach to inquiry-based experiences grounded in real-world context

19. What follows is an overview of the defining characteristics of engineering practice that have informed a philosophy of learning engineering, including what content engineering students should learn and how they should learn it. The analysis will provide the foundation for comparing the philosophy of learning engineering to a Native framework for learning - the Diné Philosophy of Learning - and understanding the potential areas of discontinuity and areas of support for a Navajo student’s education in engineering.

**Engineering Practice Drives the Philosophy of Learning Engineering**

The practice of engineering is changing. Indeed, those changes are what underlie the urgency I feel for a new approach to engineering education. Growing global competition and the subsequent restructuring of industry, the shift from defense to civilian work, the use of new materials and biological processes, and the explosion of information technology - both as part of the process of engineering and as part of its product - have dramatically and irreversibly changed how engineers work. If anything, the pace of this change is accelerating.

This was William Wulf’s - former president of the National Academy of Engineering – commentary on the need for engineering education reform due to the accelerating pace of change...
in engineering practice\textsuperscript{18}. Changes in the scale, complexity, and diversity of engineering problems and solutions have re-identified engineering practice and have created urgency in rethinking about how engineering students are trained for the profession\textsuperscript{1,18}. Vest writes in the article entitled “Engineering of 2020 and Beyond”\textsuperscript{1}, “Engineers of today and tomorrow must be prepared to conceive and direct projects of enormous complexity that require a highly integrative view of engineering systems”. Engineering systems is a modern view of engineering where complex, dynamic social and technical interconnections are core to conceptualizing engineering problems and solutions, and thus core to conducting engineering practice. These realities of engineering have forced a re-assessment of how students are expected to learn engineering. In the traditional educational model that was theory-deep and practice-light, learning of engineering was removed from actually doing the engineering, and yet students were expected to apply what they learned in industry once they graduated. Wulf\textsuperscript{18} comments on how in no other education for a practicing profession – medicine, law, theatre, etc. - would a student be expected to perform without learning through practice. The awareness of the need to support students in learning through doing has driven the philosophy of learning engineering to the essence of engineering practice: design.

Engineering design is the method that engineers use to solve problems and produce their outcome: an optimal solution\textsuperscript{19}. Engineering design is the common denominator across all engineered products, is what can be used to identify the presence of engineering activity, and is what makes engineering “legitimate”\textsuperscript{19,20}. Engineering design is not linear and does not take one singular form\textsuperscript{21,19}. Rather, it is a complex landscape of approaches, stages, principles, purposes, and traditions\textsuperscript{22}. Much of the engineering education community has conceptualized engineering design as a socio-economic-technical system of processes, procedures, and methods being used for the analysis, planning, selection, and optimum design of complex systems\textsuperscript{22,23,24}. Design is not stagnant, absolute, guaranteed or deterministic. Rather, it is dynamic, complex process that is a part of a greater feedback loop used by the engineer to know engineering and construct new engineering knowledge. Knowing how to do design requires a synthesis of knowledge, skills, and attitudes that are best learned by doing\textsuperscript{17}. These components are discussed in the next section.

By doing design (through heuristics), an infrastructure is provided for learning other core ideals of engineering practice, including ethical development, understanding that engineering affects the world, codes of conduct, the many publics of engineering, teamwork, and communication\textsuperscript{1,17}. Engineering practice drives the philosophy of learning engineering to one that is focused on “real” engineering work\textsuperscript{16}.

What Content Should Be Learned?

In the previous section it was established that the philosophy of learning engineering calls for learning by design. In this section, the knowledge needed to carry out the design method will be overviewed. In order to conduct engineering design, aspiring engineers must learn a distinct set of engineering knowledge, skills, and attributes. This includes knowledge of the design method and knowledge to carry the method out as, knowledge about how engineers make decisions and reason, and the skills and attributes that transcend all engineering activity. Each of the following subsections overview these areas of content that must be learned under the philosophy of learning engineering.

The design method. Aspiring engineers must learn the nature of engineering design and how to practically carry out the design method using heuristics. Across any variation of the
engineering design process the nature of design remains the same. Engineering design is systematic, iterative, purposeful, creative, and social. Aspiring engineers must also come to know that engineering design is not linear and concise. Koen writes:

Do we really believe that Neanderthals, primitive craftpersons, early engineers, or even a team of modern engineers in practice today first completely understand their problem, then completely develop their plan, next completely carry out this plan, and finally examine completely the solution obtained?

Aspiring engineers must come to know universal structures of design processes and treat them as guides for engaging in design. Table 2 presents some of these design processes found in academic and professional settings. Polya’s design process is placed in the middle because it was created for theoretical purpose and is often used by academics for problem solving and by engineers to guide their work with design problems. The phases of engineering design are chunked according to similarity across the design processes to represent commonalities and differences in the stages within the processes.

Table 2
Engineering Design Processes in Academic Settings and Professional Settings

<table>
<thead>
<tr>
<th>Academic Settings</th>
<th>Professional Settings</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Engineering is Elementary</strong></td>
<td><strong>Next Generation Science Framework (2012)</strong></td>
</tr>
<tr>
<td><strong>Ask</strong></td>
<td>Identify a need</td>
</tr>
<tr>
<td>Identify the problem and define specifications and constraints</td>
<td>Define the problem</td>
</tr>
<tr>
<td><strong>Imagine</strong></td>
<td>Generate ideas for solving the problem</td>
</tr>
<tr>
<td><strong>Plan</strong></td>
<td>Conducting research</td>
</tr>
<tr>
<td>Narrowing the research</td>
<td></td>
</tr>
<tr>
<td>Analyzing set criteria</td>
<td></td>
</tr>
<tr>
<td><strong>Create</strong></td>
<td>Find alternative solutions</td>
</tr>
<tr>
<td>Test the potential solutions by building and testing physical or mathematical models or prototypes</td>
<td></td>
</tr>
<tr>
<td>Analyze how well the solutions meet the specifications and constraints</td>
<td>Analyze possible solutions</td>
</tr>
<tr>
<td>Make a decision</td>
<td></td>
</tr>
</tbody>
</table>
Transdisciplinary knowledge to carry out the design method. Engineering knowledge is a distinct body of knowledge and guides engineers in using judgment, making decisions, and building consensus with the community for the ultimate purpose of creating an optimal solution to an engineering problem. Figueiredo conceptualizes engineering knowledge as a four-dimensional transdisciplinary model. The categories of engineering knowledge in this model are basic sciences knowledge, design knowledge, social science knowledge, and knowledge from doing. In this model, the aspiring engineer must learn to converge and internalize the knowledge found within these four dimensions in order to carry out the engineering method. Figueiredo’s four dimensions of knowledge are apparent in case studies of engineering, discussion of engineering methods, in the explication of philosophies of engineering, and are represented in the learning goals of engineering education.

Figure 3 is a conceptual map of the major sources of engineering knowledge as understood by the analysis in this paper. The conceptual map begins with engineering knowledge as the center and then expands to the four dimensions of knowledge represented by Figueiredo with links to examples of knowledge sources identified in other works on engineering. In the basic sciences, knowledge is produced through experimentation and analysis, and represents the theoretical knowledge of the sciences and mathematics. For instance, engineers must know how to use physical properties and quantities to assess an engineering device’s performance. In the social sciences, the social nature of the world must be realized, including the social complexity of the engineering teams, the needs of the end user (customer), and the social and economic values. Included in this is knowledge of cultural values and norms, including what is acceptable and expected behaviors. In the design knowledge dimension, the art of design is key. Figueiredo writes about the design dimension:

It values systems thinking much more than the analytical thinking that characterizes traditional science. Its practice is founded on holistic, contextual, and integrated visions of the world, rather than on partial visions. Typical values of this dimension include exploring alternatives and compromising. In this dimension, which resorts frequently to non-scientific forms of thinking, the key decisions are often based on incomplete knowledge and intuition, as well as on personal and collective experiences.
Also pertinent to design knowledge is knowledge built by the engineering community through consensus, including operational principles to interpret and explain how a device functions and normal configurations for what is state of the art. In the doing dimension, the engineer uses “the ability to tuck up one’s sleeves and get down to the nitty-gritty”\textsuperscript{24}. Knowledge in this dimension is acquired on the job\textsuperscript{27}. Rules of thumb or design considerations are knowledge sources in this dimension.

Figure 3. A Conceptual Map of the Major Sources of Engineering Knowledge

Figure 4 shows that the higher education learning goals for engineering, as outlined by the Accreditation Board for Engineering and Technology (ABET), align with the transdisciplinary model presented above in Figure 3. The engineering learning goals for modern day engineering as listed by ABET\textsuperscript{32} are:

A. An ability to apply knowledge of mathematics, science, and engineering
B. An ability to design and conduct experiments, as well as to analyze and interpret data
C. An ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability
D. An ability to function on multidisciplinary teams
E. An ability to identify, formulate, and solve engineering problems
F. An understanding of professional and ethical responsibility
G. An ability to communicate effectively
H. The broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context
I. A recognition of the need for, and an ability to engage in life-long learning
J. Knowledge of contemporary issues
K. An ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.
All of these learning goals but one, learning goal (I), is represented as engineering knowledge in Figure 3. Learning goal (J) is represented as both doing and design because contemporary issues are both informed by social understanding and knowledge of contemporary design issues.

Figure 4. A Conceptual Map of ABET’s Learning Goals and Engineering Knowledge

Figure 5 shows that the knowledge, skills, and attributes that engineers must learn, as represented by Sherri Sheppard and the Carnegie Foundation for Advanced Teaching in Educating Engineers, also aligns with the above model in Figure 3. Sherri Sheppard and the Carnegie Foundation for Advanced Teaching conceptualize engineering knowledge, skills, and attributes into knowing that, knowing how, knowing why, and knowing to. “Knowing that” represents factual and conceptual knowledge and skills related to fundamental science and mathematics concepts. Included in this way of knowing is how to communicate in mathematical terms – engineering’s second language. Knowing that is mapped to the basic sciences dimension of knowledge in the conceptual map. “Knowing how” represents the strategic knowledge and skills that enable the application of the factual and conceptual knowledge. This is mapped to the knowledge dimensions of design and doing, where students apply knowledge to solve engineering problems. “Knowing why” is the engineering intuition that comes from doing engineering. In Figure 3 this knowledge included gaining expertise in the practical environment and understanding rules of thumb and other heuristics. Finally, “knowing to” encompasses all the knowledge needed to perform the engineering method: engineering design. In the conceptual map, this represents the convergence of all knowledge sources.
Engineering decision-making and reasoning. As stated above, aspiring engineers are expected to learn to converge the sources of engineering knowledge to accomplish engineering design. But how do aspiring engineers learn to use engineering knowledge to use judgment, make decisions, and build consensus during the design process? They learn reasoning through heuristics. Polya\(^\text{26}\) writes, “Heuristic reasoning is reasoning not regarded as final and strict but as provisional and plausible only, whose purpose is to discover the solution to the present problem”. This enables engineers with the flexibility needed for determining the most logically compelling argument for the context. Acceptance of a heuristic depends on whether it works and is useful in a specific context. For example, one task engineers face is optimizing solutions for particular factors. Through heuristics reasoning, engineers might rely upon heuristics of operational principles and normal configurations to assess how a solution is performing and how it needs to be optimized. As engineers create and use heuristics to guide their work, they gain expertise that informs their work. This contributes to the consensus-building nature of engineering which is used determine best practices\(^\text{19}\). Best practices are the building blocks to determining what is state of the art and is a function of time and other contextual factors\(^\text{19}\). Determining what is state of the art through heuristic reasoning guides engineering practice to its goal: to develop an optimum solution for the design problem at hand.

The values and attributes of engineers. To guide the work of engineers, the engineering profession has designed codes of conduct. These codes “acknowledge the overall mission of the profession as contributing to human welfare” and that engineers must be competent\(^\text{17}\). The attributes that engineers must possess to they do their work are: practical ingenuity, strong
analytical skills, discovery and design, creativity, communication, accountability, ethical considerations, mastery of principles of business and management, professionalism, and life-long learning. These values and attributes are considered key to developing well-rounded engineers who can be expected to be competent in the workplace and be a contributor to solving modern-day engineering problems.

**How Should Students Learn Engineering Content?**

The traditional linear progression for teaching engineering - where a broad coverage of many technical and theoretical concepts are taught and then applied in a design experience in the final year of schooling - is no longer useful in helping students cope with the complexity and flux of engineering practice. Sheppard and the Carnegie Foundation for Advanced Teaching conceptualized a networked model that is “structured by the demands of professional practice” and support students in understanding the interconnections between the scientific, technological, contextual, and ethical dimensions of engineering work. The spine of this model is design and laboratory courses where students can use a practice-based approach to understand how engineers formulate and solve problems. Under this networked model, the way in which engineering is taught and the content that is taught is reframed and restructured. While there may be differences in conceptualizations for models of the teaching and learning of engineering, the engineering education community at large agrees that an engineering education should align with professional practice by structuring a curriculum around design experiences. To elaborate, this model emphasizes the need for learning “usable knowledge” to connect engineering thinking with action. Usable knowledge includes concepts, tools, and procedures. Because the learning of usable knowledge is best learned through active construction, the philosophy of learning engineering values “studio teaching, team projects, open-ended problem-solving, experiential learning, and the philosophy of CDIO (conceive/design/implement/operate)”. Through these pedagogical strategies, students are expected to develop a hybrid of engineering knowledge, skills, and attitudes that will allow them to function in the workplace.

This model for learning is radically different than traditional modes of learning and so two issues arise. One issue is determining how students should be assessed and the other is determining the role of the teacher in the classroom. Under the philosophy of learning engineering, assessment should not be solely based on summative evaluations of technical proficiency, but should evaluate students on the things that matter in professional practice, including the ability to engage in the iterative nature of engineering, the ability to operate within bounds of uncertainty, and the ability to possess social skills important to engineering (e.g. ability to work with teammates and ability to seek understanding of customer needs). In this case, formative assessments for the purpose of providing the student with defined, clear feedback and ensuring that students are developing value for lifelong learning are important. As for the role of the teacher in the engineering classroom, cognitive apprenticeship is key to the philosophy of learning engineering through pedagogical strategies such as modeling representations of practice, scaffolding to imitate representations of practice, coaching to support students in achieving competency, and fading out scaffolding as students become more competent. Vest quotes Murray Gell-Mann as saying, “We need to move from the sage on the stage to the guide on the side”. This communicates the perspective that students must own their learning through experiencing and reflecting upon activities that simulate engineering practice.

Design-based learning is considered by many as ideal for engineering education because it provides students with opportunities to lead and direct their own learning, learn in context,
begin to build expertise in learning environments that resemble professional practice and expect students to apply knowing to or the synthesis of the different knowledge sources to accomplish engineering design.\textsuperscript{17,28,29}

**Summary: What is the philosophy of learning engineering?**

The philosophy of learning engineering is rooted in the method of engineers – design. Design is an active, dynamic, contextualized, practical process. In order to learn engineering design in its complexity, students must learn by doing design. This constructivist approach supports the nature of engineering and engineering design in two ways: (1) it allows engineering students to have meaningful experiences with engineering as an approximation to what is represented in engineering practice and (2) it allows students to learn to synthesize multiple knowledge sources (social sciences, basic sciences, design concepts, and tacit knowledge) and skills (practical ingenuity, analytic judgment, communication, etc.) for the needs of the engineering design. Traditional schooling where students receive a one-way transmission of knowledge does not work for engineering design because engineering is heuristic and therefore does not follow one set path. Engineering design depends on a complex system of interacting phases, needs, people, and decision-making processes. This constructivist approach is often represented in the classroom through engineering design challenges, problem-based learning, or project-based learning – all of which support students in using engineering knowledge for practical purpose. The philosophy of learning engineering will be used in the final section to evaluate how it might fit with the Diné Philosophy of Learning.

**Evaluating Engineering’s Fit to the Navajo Framework for Learning**

This section evaluates the fit of the philosophy of learning engineering to the dimensions found within the Navajo framework for learning, based upon the Diné Philosophy of Learning\textsuperscript{3}. Table 2 represents these dimensions that are under analysis as well as the core points within the Navajo framework for learning and engineering framework for learning. The dimensions are color-coded to represent those areas that are congruent to one another (green) and areas of caution because they may pose a challenge to the Navajo worldview (yellow).

For dimension one, the purposes of the two philosophies are fundamentally different. In the Diné philosophy the purpose is based upon a higher, spiritual rationale: to reach hózhó (a state of peace, happiness, and plenty where balance and harmony can be achieved) and to learn behavior applicable to hózhó. In engineering, however, the purpose has a micro-focus on creating an optimal solution for a present-day human need. These two purposes do not oppose one another because they address different functions. Engineering’s focus on design means that it is principled upon creating new things (tools, systems, processes, etc.). These “new things” (engineering solutions) can be created to uphold the Diné purpose. To carry this out, knowledge and methods will be of concern. For the philosophy of learning engineering to support the Navajo worldview, the quest for balance and harmony should be recognized.

Dimension two represents the types of problems that are of concern in the philosophies of learning. The types of problems in the two philosophies are different from one another due to a matter of scale, but do not challenge one another. What is of concern in Diné philosophy are all of life’s problems. Grounded in sacred knowledge, the Navajo framework for learning is a guide for all of living in order to reach the higher, spiritual purpose. In engineering, the types of problems are constrained to design problems. Despite the micro-focus of engineering problems
compared to the Diné philosophy, the two types of problems are congruent to one another: they are practical, complex, ill-structured, and context-specific. One possible area of discord, however, is when the Navajo worldview is not used to identify design problems. The Navajo worldview must be lens in which engineering design problems are identified and understood in order for the two philosophies to have complete congruency. The Navajo worldview is needed for problems that affect Navajo life and global problems because it enriches the understanding of all possible aspects of the problem. The grand challenges in engineering today could benefit from a Navajo worldview, particularly those that concern the environment because traditional Navajos have developed and recognized a relationship with the environment. Navajo sacred knowledge stresses the importance of having respect for the Earth (and all other sociocultural beings – animals, humans, supernatural, etc.) and holistic thinking. This Navajo worldview – and any worldview for that matter – contributes to how engineering design problems are identified and what is considered a human need and why.

The third dimension addresses the representation of a solution to the problem. In the Navajo framework for learning, a solution to life’s problems is one that is reached through the appropriate methods and one that upholds Navajo values through sacred knowledge. In engineering, the solution to a design problem takes a technological form and is optimal if it is the best change for the available resources. An engineering design solution is not rigid and is evaluated against the criteria and constraints determined from the process of understanding the problem. If a Navajo worldview is used to understand and clarify the problem and evaluate the solution, then the engineering solution should support Navajo values. In Table 3, this dimension is marked as yellow (an area of caution between the two philosophies) because predominant White groups have largely controlled modernization. This could lead to a possible view of engineering as one that is more exclusive of cultural values than inclusive. Communicating that engineering solutions should meet the cultural and social aspects of human need will be key to enriching engineering education to one that is inclusive to non-mainstream groups.

The fourth dimension is the method that is used to solve problems. Both methods for the Navajo framework for learning and engineering learning use heuristics to solve problems. In Navajo framework, the method is a general problem solving heuristic that can be used for all of life’s problems. The purpose is to help people find direction within themselves, community, and environment. In engineering, the method is contextualized to design. The Navajo method is guided by the sacred knowledge found in the four directions where thinking, planning, implementing, and reflecting/assuring take place. Polya’s26 model of understanding the problem, carrying out the plan, looking back to see if the solution has been achieved, and improving is a theoretical, general problem solving model used by engineers. The Diné four-directional method for problem solving is similar to Polya’s26 model in that it is a general problem solving guide and can be useful heuristic for engineering design. Semken34 uses the Diné four-directional method in his work in geosciences. Labeling the Diné method as a “natural order” paradigm that is empirically-derived by the Navajo, Semken34 uses it to explain natural Earth cycles, including dynamic equilibrium in natural systems. The nature of the Diné four-directional method is similar to the nature of engineering design in that they are systematic, cyclical, dependent upon reflection, not absolute or rigid, and an active process for practical purpose. The Diné four-directional method also requires accessing all parts of the self – physical, emotional, and spiritual – and having respect for all sociocultural beings in order for the method to function properly. The nature of engineering design does not invalidate this reverence for the self and others
through its identity as a socio-economic-technical process that is used to know engineering and construct engineering knowledge.

The fifth dimension addresses how decisions are made. In the Navajo framework for learning, Native logic and decision-making is defined by the tribal values, including kinship, relations with all natural things, and a combined physical and metaphysical reality. In engineering, decision-making is reasoning through heuristics. The Navajo framework for learning and philosophy of learning engineering both rely upon community and consensus to establish appropriate codes of conduct that inform decisions. Also, both philosophies of learning support decision-making through a systematic, reflective practice and emphasize the role of tacit knowledge, or knowledge acquired through experiencing and doing. Intuition is supported by both philosophies of learning, but the metaphysical component that is core to the Navajo framework for learning is not addressed in the philosophy of learning engineering. This dimension was marked as a caution point (yellow) for this reason.

Dimension six is the sources of knowledge found within the two philosophies. As has been discussed, the Navajo framework for learning and philosophy of learning engineering support one another in the view that knowledge is actively constructed, used for practical purpose, is embedded in social context, and represents a synthesis of different knowledge forms. The social sciences (the importance of social and cultural norms and communication), design concepts, and tacit knowledge are congruent with the Navajo framework for learning. However, the engineering knowledge dimension of the basic sciences poses a threat to the Navajo worldview. The Western philosophical underpinnings of the theoretical sciences frame the discipline as a quest for a universal truth through empirical data and often exclude spiritual components. Furthermore, conceptions in science, such as what does it mean to be alive, is at odds with the Navajo worldview where alive is present in all natural things (the dirt, the air, etc.). To reconcile these philosophical differences, engineering educators will have to examine how the basic sciences are presented to minimize the tension with the Navajo worldview.

Dimension seven and eight address the ontology of the philosophies (reality and identity). From this evaluation, more information is needed to determine how an engineering ontology may challenge a Navajo ontology. For this reason, it was marked in Table 3 as a caution point. What has been shown in this paper is that the Navajo reality is centered on holism, cycles, and a dualistic understanding of the world where the physical and metaphysical cannot be separated. The reality in engineering is one that is focused on creating the physical world. The physical creations are oriented around revision and therefore always changing. Universal truths are not of concern in engineering reality, but rather what is solvable within the given context. The identity of engineering is to create change for human needs. The Navajo’s identity is a sociocultural product. Navajo identity is based in tribal values through sacred knowledge, kinship, and upheld through language and oral histories. Despite core differences, both philosophies of learning expect competency. The Navajo framework for learning expects competency in cultural values and an understanding of the Navajo worldview. Engineers expect professional competency. Also, both philosophies emphasize community and language, but the justifications are different. In the Navajo framework for learning, the language is what connects the Navajo people to their past and present. In engineering, mathematics is considered a second language. Although the realities and identities are not fully congruent, they do not oppose one another. However, more information is needed to assess the possible threats to a Navajo reality and identity.

The ninth dimension asks what is learning. In both philosophies, learning is achieved by doing and reflection in the practical environment. Both philosophies also uphold the learning of
complex systems, although the system addressed by Diné philosophy is on a higher order of magnitude. The purposes of learning are different which affects the end goal, but the processes to get there within the two philosophies are congruent. Represented in the Navajo framework for learning, but not in engineering, is the self’s integration in the complex, natural world. Engineering is not concerned with understanding the self or anything outside of the engineering problem at hand.

The tenth dimension is what is education. Navajo education and engineering education both stress meaningful learning situated in relevant context (for the Navajo framework for learning this is the Navajo way of life and for engineering it is a design context). In the DPL, all of learning is situated within the Navajo worldview. In the philosophy of learning engineering, education takes a constructivist form through problem-based learning models. Additional analysis is needed to identity how the Navajo worldview is supported within a constructivist engineering curriculum.

The final dimension addresses what values should be upheld. The values that are similar are: analytical skills, reasoning, planning, systematic organizational skills, accountability, quality, communication, competency, and life-long learning. The values that are represented in the Navajo framework for learning but not engineering are: self-direction based on personal values consistent with society’s moral standards, confidence, and natural order of democracy. The values of engineering that are not represented by the Navajo framework for learning are: practical ingenuity, creativity, design and discovery, professionalism, and mastery of business principles. Because of the overlap of many similar values, this dimension was marked as congruent.

This assessment provides an initial overview of the dimensions of the two philosophies of learning and what dimensions of engineering may challenge the Navajo framework for learning. A summary of what is presented in this section is found in Table 2.

Table 2
Comparison of the Navajo Framework for Learning and the Philosophy of Learning in Engineering

<table>
<thead>
<tr>
<th>Dimension</th>
<th>Diné Philosophy of Learning</th>
<th>Philosophy of Learning in Engineering</th>
</tr>
</thead>
<tbody>
<tr>
<td>What is the purpose of learning?</td>
<td>To reach hózhó – a state of peace, happiness, and plenty where balance and harmony can be achieved – and to learn behavior applicable to hózhó</td>
<td>To create an optimal solution for a human need</td>
</tr>
<tr>
<td>What types of problems are of concern?</td>
<td>All of life’s problems</td>
<td>Design problems</td>
</tr>
<tr>
<td></td>
<td></td>
<td>The nature of design problems:</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Complex</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Practical</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Solvable</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Ill-structured</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Context-specific</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• No definitive solution</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Design problems of concern today:</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Social</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Economic</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Ecological</td>
</tr>
<tr>
<td>What might a solution look like?</td>
<td>One that is guided by sacred knowledge</td>
<td>Technological development that is:</td>
</tr>
<tr>
<td></td>
<td>• One that converges and internalizes all knowledge forms placed by the</td>
<td>• Optimal for the problem need</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• The best change for the available</td>
</tr>
<tr>
<td>Question</td>
<td>Response</td>
<td></td>
</tr>
<tr>
<td>----------</td>
<td>----------</td>
<td></td>
</tr>
</tbody>
</table>
| What is the method used to solve problems? | • Use the knowledge found in and behaviors guided by the four directions  
  - Thinking  
  - Planning  
  - Living/Implementing  
  - Reflecting/Assuring  
  • Access all parts of the self (emotional, physical, and spiritual)  
  • Recognize the circuitry of life  
  • Be guided by the songs, prayers, and stories told by elders  
  Heuristics = Engineering Design  
  The nature of engineering design:  
  - Active  
  - Not one singular form  
  - Structured differently to achieve different functions  
  - Complex approaches, stages, and principles  
  - Not absolute, guaranteed, or stagnate  
  - Dynamic, complex  
  - Systematic, iterative, purposeful, creative, and social  
  - Used to know and do engineering  
  - Used to construct new knowledge and new technological developments  
  - Socio-economic technical process |
| How are decisions made? | Reasoning through four directions  
  - Thinking  
  - Planning  
  - Living/Implementing  
  - Reflecting/Assuring  
  Consideration for  
  • All sociocultural relationships (Earth, animals, humans, supernatural, etc.)  
  • Physical and metaphysical reality  
  • Tribal values  
  • Environmental determinism  
  • Group identity  
  Reasoning through heuristics  
  • Focus on most logically compelling arguments  
  • Feedback from design methods and throughout the process  
  • Consensus-building with the community |
| What is knowledge? | Knowledge is within the  
  • Physical world  
  • Spiritual world  
  Knowledge is sacred and within all things  
  Knowledge is active  
  Knowledge is trans-disciplinary:  
  • Design  
  • Basic Sciences  
  • Social Sciences  
  • Doing  
  Knowledge is embedded in a social context |
| What is reality? | • Dualistic reality where the physical and metaphysical spiritual world cannot be separated  
  • Holistic  
  • Cyclical  
  • Always changing  
  • Universal truth not of concern  
  • Oriented around revision |
| What is identity? | • Group identity through kinship  
  • Upheld through language  
  • Told through oral histories of stories, prayers, myths, and legends  
  • Sociocultural embodiment  
  • To create the world that does not exist yet  
  • Centered on human need |
| What is learning? | • To learn to internalize and converge all knowledge forms required to  
  • To converge all knowledge, skills, and attributes to be competent |
<table>
<thead>
<tr>
<th>What is education?</th>
<th>What values should be upheld?</th>
<th>The source for engineering values is found in the engineering codes of conduct.</th>
</tr>
</thead>
</table>
| Development of Diné educational models to uphold tribal values and knowledge  
  - Diné character-building standards in K-12  
  - Diné Educational Philosophy at the Diné College | The source of Dine values is found in the Dine frameworks for learning  
  - Reasoning  
  - Planning  
  - Communication  
  - Systematic organizational skills  
  - Self-direction based on personal values consistent with society’s moral standards  
  - Quality  
  - Participation  
  - Competency  
  - Confidence  
  - Communal philosophy  
  - The whole community is greater than the singular  
  - Kinship bonds people  
  - Natural order of democracy  
  - People are a part of the environment, not above it  
  - Respect for all sociocultural relationships (humans, animals, plants, landscape, supernatural, etc.) |  
  - Practical ingenuity  
  - Analytical skills  
  - Discovery and design  
  - Creativity  
  - Communication  
  - Accountability  
  - Mastery of business principles  
  - Professionalism  
  - Life-long learning |

**Conclusion**

This paper describes a Navajo framework for learning and evaluates the philosophy of learning in engineering to the Navajo framework, bringing attention to the areas of discord and the areas that support one another. The objective of this paper was to gain an understanding of the beliefs and ideas within the philosophies of learning for the Navajo context and engineering context. Furthermore, the purpose of this evaluation was to determine how an engineering education could be situated within the Navajo worldview to strengthen a Navajo student’s access to and persistence in engineering. Engineering needs diversity within its work force if we are to understand the full dimensions of the problems at hand and solve many of our modern day challenges.
Donald Fixico’s\textsuperscript{2} conceptualization of the Native worldview as the “Medicine Way” offers a rich analysis of what it means to think like an “Indian”. Fixico builds a conceptual map of the Native American viewpoint that confirms what Benally created in the DPL. The Medicine Way is a Native paradigm where the physical and metaphysical realities are one and there is power in all things. Key components of the Medicine Way are: cultural values – kinship, Native language, and Natural Democracy (people are a part of the environment not above it), communal philosophy, oral tradition to communicate myths and legends, Native dualistic reality of the physical and metaphysical, harmony and balance, and so on\textsuperscript{2}. These ideas are represented in the DPL, contextualized specifically to the Navajo ways of knowing and logic. “The design way” conceptualized by Harold Nelson and Erik Stolterman\textsuperscript{30} offers a juxtaposition to Fixico’s ideas. In the design way, design is a way of knowing that brings together thinking and doing, encourages reflective practice and judgment, and has been around since the beginning of time as people design their environment and relations in their environment. These ways of knowing are represented in the philosophy of learning engineering. By thinking through these ways of knowing and corresponding philosophies of learning, an understanding of what it means to be Navajo, learn within a Navajo framework, and how the learning of engineering could fit within the Navajo framework is implanted. As engineering educators move forward in transforming learning experiences and environments for students, non-mainstream ways of knowing must be considered to provide access to all groups of people and therefore grow a professional base of engineers that is diverse in skill and background.

References


