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### Exploring American Indian Students' Problem-Solving Propensity in the Context of Culturally Relevant STEM Topics

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ORIGINAL ARTICLE

# 문화 반영적 융합교육(STEM) 주제 상황에서 미국 토착민 학생들의 문제 해결 성향에 대한 탐색

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## Exploring American Indian Students' Problem-Solving Propensity in the Context of Culturally Relevant STEM Topics

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### ABSTRACT

This study presents an out-of-school problem-solving lesson we designed for American Indian students using a culturally relevant STEM topic. The lesson was titled "Shelter Design for Severe Weather Conditions." This shelter design lesson was developed based on an engineering design allowing us to integrate STEM topics within a traditional indigenous house-building context. This problem context was used to encourage students to apply their prior knowledge, experience, and community/cultural practice to solve problems. We implemented the lesson at a summer program on an American Indian reservation. Using the lesson, this study explores how American Indian students use cultural knowledge and experience to solve a STEM problem. We collected student data through pre- and post-STEM content knowledge tests, drawings and explanations of shelter models on the students' group worksheets, and classroom observations. We used interpretive and inductive methods to analyze the data. This study demonstrates that our culturally relevant, STEM problem-solving lesson helped the American Indian students solve a complex, real-world problem. This study examines how students' prior experiences and cultural knowledge affect their problem-solving strategies. Our findings have implications for further research on designing problem-solving lessons with culturally relevant STEM topics for students from historically marginalized populations.

**Key words** : engineering design, problem solving, STEM education, culturally relevant curriculum

### 1. Introduction

As scientific knowledge and technology change

rapidly, schooling is necessary but not sufficient for supporting lifelong literacy in STEM (Science, Technology, Engineering, and Mathematics) fields

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(Dierking, 2007). Increasing evidence supports the claim that out-of-school science education programs positively affect youth development, critical thinking, and academic excellence (Koke & Dierking, 2007; Miller & Pardo, 2000).

Well-designed, out-of-school STEM programs can encourage youth in marginalized populations, such as American Indians, to pursue academic careers in science and can shed light on the inequities in traditional STEM education (Fadigan & Hammrich, 2004; Park, Nam, Moore, & Roehrig, 2011). In particular, research has shown that out-of-school education programs positively affect underserved students' science achievement (Rand Corporation, 2005). Thus, out-of-school STEM education programs are considered as an important way of complementing K-12 STEM education for minority youth.

However, most of the youth participating in informal science programs are from higher socioeconomic status (SES) families, and thus have more parental support (Larson, 2000). A relatively low percentage of youth from poor households and/or minority populations are successful in their pursuit of STEM-related careers (Babco, 2003). Issues of disparity in equity and access in the STEM pipeline among minority and/or low-income students (e.g., American Indian, African American, and Hispanic youth) are the most prevalent challenges for improving US STEM education (e.g., Morgan, Farkas, Hillemeier, & Maczuga, 2016). It is critical for these populations to have more opportunities, including informal learning opportunities, to address their underachievement and underrepresentation in STEM and STEM-related careers (e.g., Crisp, Nora, & Taggart, 2009).

One of the most important goals of out-of-school STEM education is to improve students' abilities to solve complex, real-world problems within STEM contexts (National Academy of Sciences, 2006). Yet, there are few studies of how minority students' prior

knowledge—shaped by their socio-cultural context and home environment—affects their problem-solving strategies (Lave & Wegner, 1991). A problem can be perceived and solved in different ways, depending on the problem-solvers' beliefs, cultural practices, values, prior knowledge, and past experiences (Jonassen, 2000). Thus, when we design problem-solving lessons for minority students, we need to consider students' prior knowledge, constructed within their cultural context.

According to Sodian and Bullock (2008), students who participate in carefully designed investigations of complex, real-world problems acquire STEM content knowledge and meta conceptual knowledge about the nature of scientific inquiry. While most science educators and cognitive psychologists regard problem solving as an important learning outcome, we need more research on STEM problem-solving pedagogy, especially in serving students from marginalized populations, such as American Indian youth. By using a problem-solving literature review and culturally relevant pedagogy, we examine how students' cultural knowledge and everyday experiences affect their problem-solving strategies in real-world contexts.

## II. Literature Review

National curriculum documents in science and mathematics, including the National Science Education Standards (National Research Council, 1996) and the National Council of Teachers of Mathematics (2000) have emphasized the importance of problem solving in real-world contexts. Yet, scholars and practitioners have voiced concerns that the problems students solve are often “inconsistent with the nature of the problem[s] the students will need to learn to solve in their everyday life” (Jonassen, 2000, p. 63). Recent research in problem solving and scientific reasoning claims that problem-solving skills are domain and context specific. Thus, these skills are dependent on

the problem-solver's experiences in similar contexts (e.g., Amsel et al., 2008; Jonassen, 2000).

From the perspective of constructivism, problem-solving techniques will vary based on how the problem is presented and how it is perceived by the problem-solver (Jonassen, 2000). Students perceive a problem differently based on their prior knowledge and past experiences. Their approach to solving a problem is affected by their social environment. For example, students are influenced by how their peers solve similar problems. Thus, we need to consider students' prior knowledge, past experiences, and social environment when we design problem-solving instruction. These factors shape students' development of problem-solving skills and acquisition of specific knowledge (Savery & Duffy, 2001).

Culturally relevant science teaching recommends using students' cultural knowledge and everyday life experiences as important teaching and learning resources (Gay, 2000). Culturally relevant science teaching has also been considered as a promising approach to promote academic success for a variety of minority communities, including American Indian youth (e.g., Gutstein, Lipman, Hernandez, & de los Reyes, 1997; Johnson, 2011; Matthews, 2003).

Researchers who advocate a culturally relevant approach to teaching encourage incorporating minority students' prior knowledge, past experiences, and community/cultural practices into lessons (e.g., Deyhle & Swisher, 1997; Gay, 2000; Gonzalez, 2005; Lee, 2004; Pewewardy & Hammer, 2003). Using a familiar cultural base and/or experiences in teaching allows minority students to more easily relate to the lessons, thus empowering them to build on their own knowledge (Barba, 1995; Menchaca, 2001). By using this wealth of knowledge from a familiar cultural base and experience as teaching resources, teachers can help minority youth engage in learning science (Davies, 2006). This approach also makes learning science more meaningful and relevant to students'

lives (Bryan & Atwater, 2002) and helps students develop a sustainable interest in science (Basu & Barton, 2007).

A culturally relevant approach in teaching is particularly important in helping minority students improve achievement in STEM. The persistent academic achievement gaps between White and underserved, low-income groups, including American Indian youth in STEM and in STEM-related careers, is a critical issue in the US (e.g., Babco, 2003; Fadigan & Hammrich, 2004; Rand Corporation, 2005). This underachievement and underrepresentation of minority and/or low-income students in STEM fields result from both opportunity gaps, including lower access to high-quality education and informal learning, such as out-of-school programs (Hillemeier, Morgan, Farkas, & Maczuga, 2013; Ramani & Siegler, 2008), and curricula in which Western culture is the norm (e.g., Menchaca, 2001).

Thus, we must adjust instructional methods to fit our students' cultural and everyday life contexts. We must also account for differences in learning styles (More, 1987; Pewewardy, 2002; Preston, 1991) and communication styles of American Indian youth (Greenbaum, 1985) nurtured in students' homes and communities (Pewewardy & Hammer, 2003). According to Preston (1991), students from American Indian communities are often successful at tasks that test visual and spatial abilities and involve simultaneous processes. Preston (1991) suggested that experiential and cooperative learning might be two particularly effective techniques to engage children from American Indian communities in problem solving.

Out-of-school programs usually create exciting opportunities for learning. These curricula involve various activities that are typically more active, hands-on, and engaging for students. They are often not found in formal classrooms. According to Friedman and Quinn (2006), seventy-five percent of

Nobel Prize winners had a chance to develop their passion in subject areas, which are often not available in formal school programs, during out-of-school programs. More importantly, out-of-school programs can help American Indian youth improve their interests and achievement in science (Fadigan & Hammrich, 2004; Park et al., 2011).

Existing studies develop “problem solving” as an instructional model for teaching (e.g., English, 2008; Lesh & Doerr, 2003; Savery & Duffy, 2001). In particular, engineering design activities, which are a type of problem-solving activity in realistic situations, permit the integration of STEM topics with contexts. While engaging in engineering design activities, students develop a better understanding of mathematics, science, and engineering concepts. Engineering design also provides them with opportunities to develop higher-order-thinking skills (Carpenter & Romberg, 2004; Lesh, Lester, & Hjalmarson, 2003; Moore, Miller, Lesh, Stohlmann, & Kim, 2013). We use these studies, as well as our original framework to design our instructional model through problem solving for American Indian youth. We use real-world STEM topic shelter design to develop culturally relevant STEM instruction for American Indian students.

Existing studies have also examined the effects of instructional choices on a student’s acquisition of problem-solving strategies. For example, Strand-Cary and Klahr (2008) assessed the effects of direct instruction on third- to fifth-graders’ acquisition and long-term retention of the control variable strategy. They showed that teaching the control variable strategy explicitly helped improve students’ understanding of the concept. Sodian, Jonen, Thoermer, and Kircher (2006) similarly demonstrated that instruction on experimentation, which focused on the experimental design, improved fourth-grade students’ understanding of problem-solving strategies. Dean and Kuhn (2007) also argued that explicit

instruction led to a higher rate of immediate strategy acquisition than exploratory conditions. These studies support the idea that instruction for elementary students to improve problem-solving skills needs to include reflections on the experimental design or control variable strategy (Sodian & Bullock, 2008).

The above-mentioned view of problem solving naturally requires the development of a culturally relevant problem-solving lesson for minority students, mainly taught in a culturally unfamiliar learning environment (Barba, 1995). Culturally relevant STEM instruction allows students to make connections between STEM subjects that the students experience and the tasks/lessons (Gutstein et al., 1997; Matthews, 2003). This study presents an out-of-school problem-solving module we designed for American Indian students using a culturally relevant STEM topic. The module was titled “Shelter Design for Severe Weather Conditions.” The shelter design lesson was developed based on an engineering design allowing us to integrate STEM topics with a traditional indigenous house-building context. The problem context was used to encourage students to apply their prior knowledge, experience, and community/cultural practices to solve problems. We implemented the module at a summer program on an American Indian reservation. Our findings indicate that the participating students solved a real-world problem using their understanding of multivariate conditions, as well as their cultural knowledge.

The specific research question for this study was the following:

How do American Indian students use cultural knowledge and experience to solve a STEM problem?

### III. Methodology

#### 1. Context: Shelter Design Lesson

The shelter design lesson was developed to improve

students' engineering design skills, applying cultural knowledge and everyday life experiences. The learning context, which is based on cultural experience and knowledge, is important in making students' learning experiences more meaningful. American Indian students who participated in the study lived on the White Earth Indian Reservation, where their ancestors lived, and most of the population is Native American who still try to maintain their cultural knowledge and language. Building a shelter is considered as an important skill for survival because as the name shows, White Earth is located in a place that experiences severe weather conditions, especially during the winter. Thus, the problem-solving task for students was to "build a model shelter for three people in extreme weather conditions (heavy precipitation, extreme hot or cold temperatures, and strong wind) in a forest near the reservation." We based our approach on traditional indigenous house-building techniques, asking students to construct mainframes and waterproof coverings. Students needed to consider four conditions (shelter volume, resistance to weight, resistance to wind, and inside temperature) to solve the problem.

The shelter design lesson is a modeling activity composed of five sub-tasks to explore the given conditions. In the first sub-task, students were asked to make a paper shelter model, considering enough interior space for three people. The purpose of this lesson was to understand mathematical knowledge to design the shelter's shape and interior space. Students were asked to answer questions and draw the shelter design based on their group decision, and to build a shelter based on their design with the material they chose. In every lesson, a student worksheet with a list of questions and directions was given to the students. After each lesson, students were asked to answer a challenge question related to the topic of each lesson. The challenge question for the first lesson was, "What is a good structure for having more inner

space?" In the second sub-task, students were asked to make the best structure to resist high levels of precipitation, while keeping the first condition in mind. The purpose of this lesson was to understand a shelter structure that is resistant to heavy precipitation, such as heavy snow or rain. First students were asked to make a list of factors related to the shelter's resistance from heavy objects. Then they drew a structure that they thought would be most efficient in resisting heavy precipitation. More importantly, students were asked to reflect on their ideas by comparing them with their ideas from the first lesson. During the lesson, students refined their design based on the science experiment of adding different weights on the designed structure until they were satisfied with their final design. The third sub-task involved finding a structure that was most resistant to a strong wind from any direction. Based on their prior experience and the science experiment of blowing strong wind with a leaf blower, students refined their prior design to make it as resistant as possible to strong wind. With the challenging question, "What is a good structure for the strong wind and heavy object and having more inner space?" students considered three different variables to find the most effective shelter structure. The purpose of the fourth sub-task was to find a structure that would be effective in producing air convection inside of the shelter using a different cover design. During the lesson, students designed the cover of the shelter and decided on the location of the windows. The lesson module took one-and-a-half hours per day over six days to complete. During the first five lessons, students explored the relationships between the conditions and building structures, through experiments and hands-on shelter modeling, using the given materials. In the last lesson, they built a final model shelter based on their experimentation, and they developed guidelines for other audiences. Figure 1 shows the hands-on science experiments and the students' shelter-designing for each task.

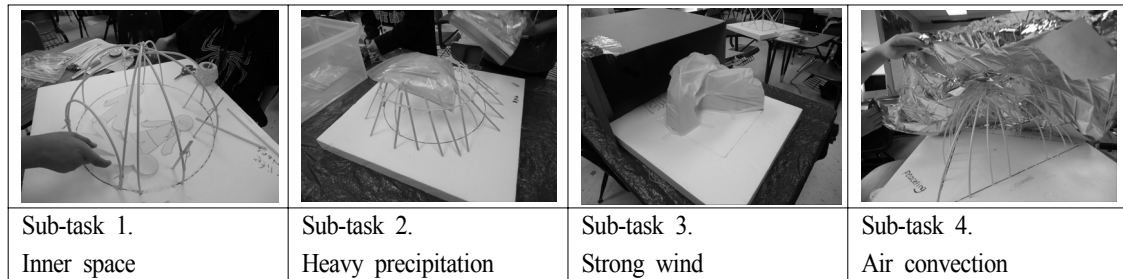


Fig. 1. Students' shelter design example for each sub-task.

Teachers' behaviors play an important role with what does and does not work in American Indian classrooms (Clearly & Peacock, 1998). In American Indian classrooms, teachers need to build trust and strong relationships with students, and they must connect to community practices to establish cultural relevance. The authors of the study and one more researcher were the main designers and instructors of the lessons. We used an engineering design cycle as the main framework to design and implement the lessons. To encourage the students to use their cultural knowledge and experience in a freer atmosphere, we decided not to mention the cultural background of their traditional shelter design. The lesson was delivered during the summer program "Reach for the Sky (RFTS)," funded by the NSF ITEST (Information Technology Experiences for Students and Teachers) to engage American Indian youth at the White Earth American Indian reservation in Minnesota. This innovative program was designed to make learning STEM (Science Technology Engineering and Mathematics) accessible and more culturally relevant to American Indians, specifically Ojibwe youth (grades 4-8).

## 2. Participants

Fifty-six, 4th-through 9th-grade American Indian students participated in the shelter design lesson for six days, one-and-a-half hours per day. All of them were from the White Earth American Indian Reservation, and they attended one of the reservation

schools. The students were descendants of the American Indian tribe called the Ojibwe. Depending on their grade, students attended the Reach for the Sky summer program more than once. Because the number of higher-grade students (7th-9th) was not enough to make a group with the same grade students, and some of them were students with disabilities, we used data from 4th-to 6th-grade student groups. Students were grouped based on grade, and they worked cooperatively to solve the tasks. A total of 16 groups of students were generated. Thus, the total number of our student participants was forty-six (eight 4th graders, sixteen 5th graders, and twenty-two 6th graders). About half of the participants (24) were male.

## 3. Data Collection

The data for this study came from four main sources: 1) students' worksheets during the lessons: five worksheets were developed, focusing on each lesson's purpose, and the students were asked to draw and explain their shelter model structures; 2) students' final shelter model and guidelines for building a shelter: students were asked to build a shelter based on the problem-solving task and to write shelter-making guidelines for general audiences; 3) classroom observations and field notes: students' discussions and group work were described by a researcher, and audio, video, and photo images were collected.

## 4. Data Analysis

Because of the qualitative and interpretive nature of

the shelter design task, we used an inductive approach to analyzing the data. That is, as Patton (2002) described, “Instead of searching for predetermined patterns, themes were allowed to emerge from the data as the authors constructed meaning from students’ responses.” In our case, these responses came from the worksheets and shelter-making guideline. First, we read the data and developed the core concepts about students’ problem-solving skills and their prior experiences and cultural knowledge. Second, we developed a table to collect evidence of these core concepts across the groups. The core concepts were categorized by each sub-task of the lessons and common concepts across the sub-tasks of the shelter structure. The concepts for each sub-task of the lesson included: the bottom shape, heavy object resistance, wind resistance, and air convection (location of the windows and door). Common concepts included the following: misconceptions (about the shape, structure, and air convection), re-useable materials, most important conditions, and final goals. Based on each concept, sixteen groups of data were categorized as a table. Finally, we looked for central themes around each core concept to answer our research questions. Two central themes emerged from the concepts: understanding the problem based on cultural knowledge and experience, and the cultural knowledge and experience used in the shelter design process. Three researchers participated in the data analysis process in order to enhance the authenticity of the interpretations and the credibility of the findings (Patton, 2002). To support the reliability of the analysis, the analysis results were peer reviewed; inter-rater reliability was above 90%.

## IV. Finding

The main purpose of the study was to determine how American Indian (Ojibwe) Students use their unique cultural knowledge and experience to solve a

problem in the context of a culturally relevant STEM topic. Based on this analysis, we found that the students’ cultural knowledge and experience affected their problem-solving process in two ways: understanding the problem and finding a solution to the problem. In the following section, we describe how the students understood the problem based on their cultural knowledge and experience, and how they used their cultural knowledge and experience to solve the problem.

### 1. Understanding the Problem Based on Cultural Knowledge and Experience

Most of the students in this study understood the lesson module’s tasks based on their personal experience and cultural knowledge. Some of the students had a strong image of how a shelter should look like or what the most important purpose of the shelter was, so they modified the purpose of the given tasks based on their personal beliefs. In addition, they often solved problems in a way that aligned with their cultural knowledge. In particular, they defined what the most important factors/conditions were, based on their cultural knowledge and experience.

First, the students had a cultural belief about the important purpose of shelter building, which is a long-term dwelling for harvesting wild rice, hunting, collecting maple syrup in preparing for the long winter in the northern United States. Many American Indian communities have strong and diverse traditions of shelter construction. Most of the students wanted to make a shelter for long-term purposes rather than the 3-5 days allotted to the task. One of students, Sarah, understood the shelter task as making a shelter for long-term purposes, and she included a door, window, and an additional smaller room. Some of the students also wanted to use bear pelts for their shelter covers. Some of the students also built a fence around the shelter, showing that they wanted to make the shelter structure more like a modern house. An additional structure to the shelter also meant that they considered



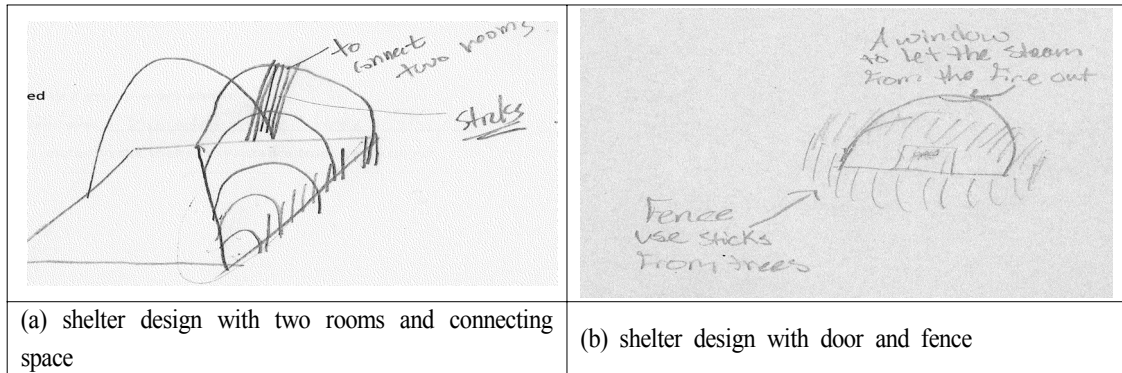


Fig. 2. Students' shelter design considering long-term stay.

the shelter as a long-term dwelling. Figure 2 presents students' drawings and shelter designs, including fences, doors, and additional rooms.

Interestingly, it seems that the students considered cold-weather conditions or winter weather when they chose the material to cover the shelter when designing the shelter for the air-convection task. They thought of the shelters as long-term dwellings rather than temporary dwellings, and they also consider the dwellings for long-term stays during the winter time. For example, Team C considered even collecting bearskins or tree bark to cover the shelter and make a long-term dwelling to prepare for winter weather conditions, as they mentioned, " ... Collect skins of bears or tree bark from birch trees ... cover by bark and then cover it up with bearskins."

Some of the students also interpreted the purpose of the task based on their personal experiences and cultural knowledge. Thus, they devised atypical solutions to the task. For example, Tamica, one of the students, wanted to place her shelter in a field to watch animals. Tamica thought that placing her shelter in a field would be safer than in a forest because she could watch animals from a farther distance there. Other students also made a fence around their shelter to protect themselves from wild animals. Most teams mentioned that shelters should be built "against a tree, and near a lake or river," to be protected from wild

animals. For the students, wild animal attacks were the most fearful and dangerous factor in a forest. As Team I mentioned, " ... In the field because a long time ago, Indians put their teepees on the edge of the forest by the field ... They watched other teepees they wanted to make sure they were all safe. Fields are safe because I can watch out for wild animals." Other groups of students also suggested the field as a safe location for building shelters.

For the students, wild animals were one of the most important factors to consider for surviving in a forest, even if this factor was not addressed in the task. In other words, students knew about the physical context of the forest from their own experience and what they needed to consider in order to survive in a forest from the knowledge of their culture.

As described above, students understood the problem based on their cultural knowledge and experience. They considered a shelter as a long-term dwelling and as a place to stay during cold weather conditions, which was not solicited as a condition of the lesson tasks. Interestingly, the students also considered animal attacks as a critical factor for surviving in the forest. This factor was not mentioned as a task in the lesson, but the students considered animal attacks as the most critical condition in building a safe shelter. This result shows that the students interpreted the purpose of the task based on

their cultural knowledge, experience, and context of the shelter design, which encouraged students to use their cultural knowledge and experience.

## 2. Using Cultural Knowledge and Experience to Solve a Problem

The lessons included multiple tasks, from designing a stable structure to resisting heavy precipitation and strong wind, to designing an effective structure for air convection. Students were asked to consider all of the conditions to decide on the final design of their shelter. We found that the students applied their cultural knowledge and experience while they accomplished each task. In particular, students demonstrated their knowledge of traditional materials for the shelter design and found safer places in the forests. More importantly, many student groups decided to use the traditional shelter structure, the wigwam, for their final structure.

First, some of the students demonstrated traditional knowledge of shelter materials. Most of the students mentioned specific tree species that they usually used in their everyday lives to make shelters or other tools. Three teams wanted to use the bark of birch trees or oak trees to cover the shelter. From their cultural knowledge and experience, students knew that the bark of birch trees or oak trees has been used for covering or making the outer frame of wigwams for a long time. In their everyday life experience, students also knew that birch or oak trees are easy to find in the forest. Students also knew that these trees were used to make traditional tools for harvesting and roasting wild rice, and in their everyday lives. Birch or oak trees are used for many different purposes in American Indians' (Ojibwe) everyday lives, such as making canoes, which is a very important transportation tool because these trees provide more durability than other tree species. In particular, one of the students wanted to make a traditional glue using the sap from oak trees to hold the materials together, as written on Team D's worksheet "To make glue, use

sap from oak trees."

Second, students applied their cultural knowledge for finding safer locations to building a shelter. The students also wanted to choose a place for their shelter where there were no dead trees because they knew that dead trees were a shelter for large insects and small animals. Many students mentioned not building a shelter on an "animal track or trail." For example, students wrote on their worksheet, "Think about where you make your shelter. Don't make a shelter on an animal trail," and "You need to make sure you need a good place to make your shelter. Don't build on animal trail." More importantly, some of the students mentioned that they also needed to be very careful about poisonous plants when using leaves and plants for building a shelter. In the list of materials they would use for the shelter, many students mentioned "sturdy branches," "leaves or debris," and more importantly, "not to use poison ivy," "not to use hollow trees," and "not by dead trees." This result shows that the students used their cultural and everyday life experiences to find safe locations for building their shelters. Considering a safer location was an important factor for them, as much as a safe structure of the shelter to survive in the forest.

Third, most of the teams decided to use the wigwam structure as the final frame for their shelter design. Many students tried different structures at the beginning and decided to use the wigwam as their final structure. In their final design, students described various types of traditional knowledge for building a wigwam, such as "using basswood tree for string to tie branches," "using dry leaves for [the] bottom," and "using birch bark for covering [the] door." One of the groups wrote in their final report, "The Roger Dot (group name) likes the wigwam shape shelter because it gave a good place to stay and it held up through the wind and the rain. The rain will run down and the wind just goes around it." Some of the students used

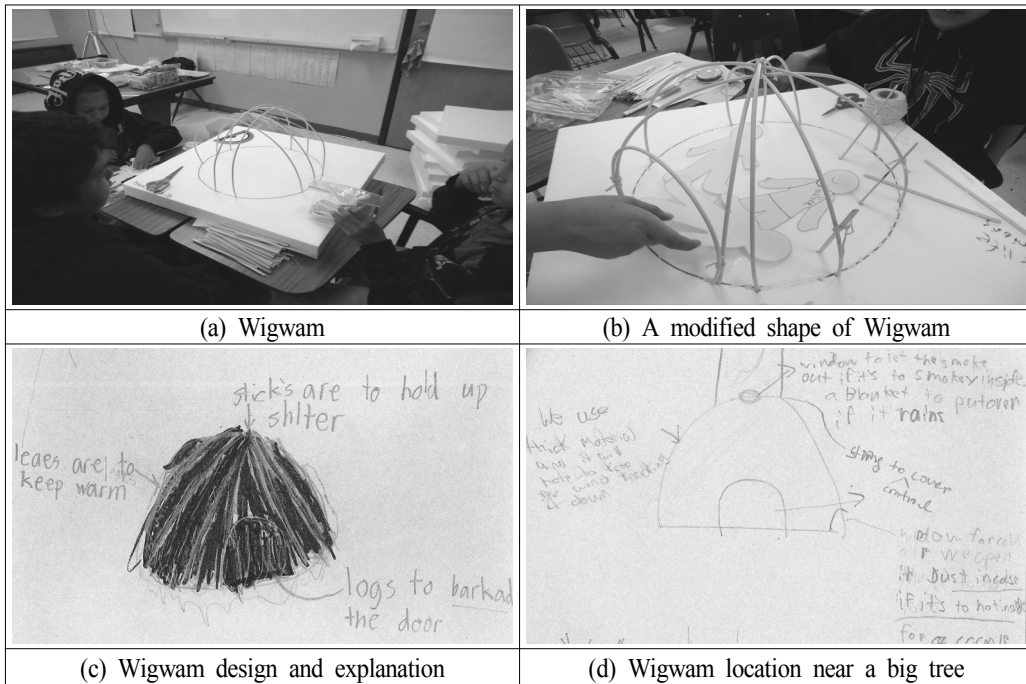


Fig. 3. Students' wigwam shelter design examples.

traditional Native American shelter shapes from other tribes and locations, such as lodge houses or teepees. As Team A mentioned, “Team A: Our design is like a wigwam. These are the shelters that Native Americans used a long time ago. A wigwam is a dome-shaped structure that is designed to keep people warm and protected from animals.” The students used the terms that were directly related to the traditional Native American shelter shapes.

Figure 3 presents samples of the students' shelter frame. Figure 1 (a) shows a wigwam structure, which is a Native American tribe's traditional shelter shape that represents the Native American people who lived on the reservation, White Earth. Figure 1 (b) is a modified version of a wigwam shape. Figure 1 (c) shows a traditional shape of teepee, which is a representative Native American shelter in the western part of the US, and (d) is the shape of a lodge house, which is frequently found in Native American tribes in the eastern part of the US.

Finally, the students' cultural knowledge about

traditional shelter design affected the ways they designed the shelter to control the inside temperature. Students' solution to maintaining the inside temperature was more focused on preserving the inside heat during the severe cold weather than on releasing the inside heat during hot weather. This result shows that most of the students considered severe cold weather conditions more than hot weather because of their geographic location. Many students wanted to cover the shelter with one or multiple layers without making windows or a hole for the air circulation to keep warm air inside. This is illustrative of a traditional wigwam construction technique. One of the groups wrote in their final report why they used multiple layers to cover the shelter: “Make two layers why? Because you could hold air between the layers. You could open one layer during the day and cover it (shelter) up with second one for night.” The students also mentioned making a fire outside of the shelter, which is a traditional Ojibwe idea. To make a fire, they use dried pine cones and leaves for material, and

string and branches for tools. Students also wanted to make a hole on top of the shelter with a cover to let smoke escape or keep it inside, at their discretion. These ideas echo traditional American Indian shelter design techniques. Thus, there were two main shelter design techniques to control the inside temperature: making a hole or window on top of or on the side of the shelter and covering the shelter with multiple layers to preserve the inside temperature. The following quotes showed how each team would keep the inside of their shelters warm.

Team E: “ ... Fire inside of the shelter ... Make a top hole.”

Team F: “ ... Two top window for smoke emission.”

Team G: “ ... One hole on top A window at the lower level to make cool air come in...”

Team H: “We’ll use two layers because you could open one layer and have more air from outside.”

Fig 4. Students’ shelter design examples with layers

Figure 4 shows examples of students’ shelter designs. In terms of their shapes, both of the designs are similar to the wigwam, which is the traditional shelter shape of the Ojibwe students on the reservation. Since the wigwam was more important during the winter as a place to stay, most of the students considered cold weather conditions during the winter in designing the shelter rather than warm or

mild weather during other seasons. However, the main idea of keeping warm air inside of the shelter was based on their traditional knowledge, such as multiple layers, using leaves for the bottom, and using mud to prevent air from leaking.

## V. Conclusion and Discussion

This study was intended to explore how American Indian (Ojibwe) youth solve a problem in a culturally relevant STEM context. From the results, it was evident that the students understood the task situations based on their cultural knowledge and everyday life experiences. They interpreted the task in ways that made the task more sophisticated and practical to their culture or everyday life. They also solved the problem by applying their cultural knowledge and experiences.

The shelter design task provided an opportunity for most of the participants to engage in a problem task that was contextually meaningful. Most of the students established their own validity by aligning the problem to their cultural knowledge and personal experiences. The American Indian students’ prior knowledge and cultural experiences of traditional shelter design helped them consider a long-term shelter design, safe location, and different construction techniques.

In addition, American Indian students viewed the

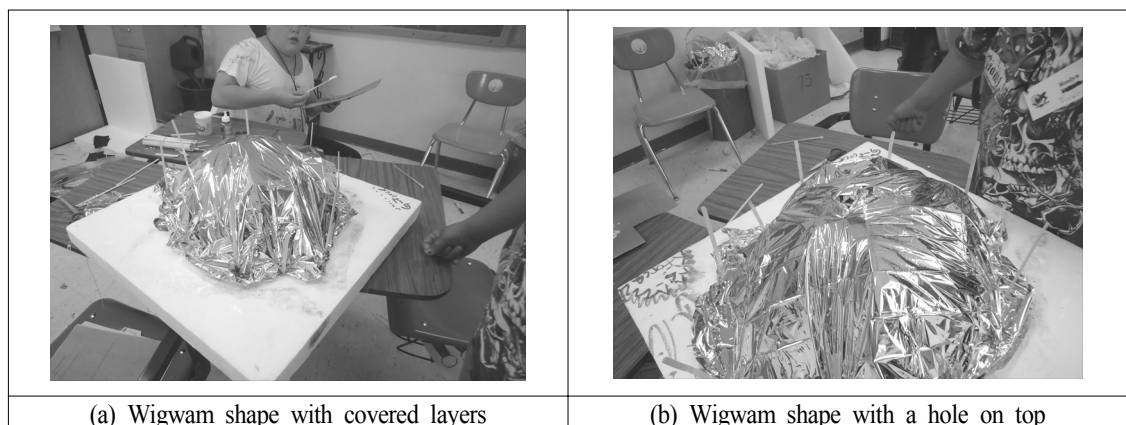


Fig. 4. Students’ shelter design examples with layers

problem-solving task as a long-term vs. short-term task. Our posed problem involved getting stranded in a place and making a shelter for a short period of time, such as three days. Yet, the students tended to solve this issue through a long-term lens. They wanted to make shelters that would last for long periods of time. This shows that the students viewed the problem through their own cultural lens.

They also understood the task as a multifaceted issue that should be resolved based on multifaceted solutions. However, most of the students' final solution of their shelter design was based on a traditional house-building structure called a wigwam. While the students kept changing their design based on the science experiments, they realized that their traditional shelter was the most effective design that could be built with the natural materials they could find in the forest, similar to their ancestors. It seems as though the students considered the materials and location of the shelter as more important factors for a safe shelter than the frame of the shelter. This means that the students' cultural and everyday life experiences greatly affected their decision of their final design. As the study shows, American Indian students' knowledge and experience are critical factors in their learning of science content and ways of approaching a problem in a real-world context (e.g., Menchaca, 2001). Recent studies have also shown that the Ojibwe's traditional view of nature and natural processes would affect Ojibwe students' understanding of scientific knowledge (e.g., Author, 2016). However, this important knowledge and experience has not been considered as an important teaching resource in American Indian classrooms (Corbiere, 2000). Unfortunately Native American communities' traditional science has not been officially recognized as important knowledge in science education (Snively & Corsiglia, 2001).

This study also demonstrates that our problem-solving module used a culturally relevant

STEM topic to help American Indian students solve a complex, real-world problem using the students' own experiences and cultural knowledge and improve their STEM content knowledge. There is increasing evidence that out-of-school programs can help American Indian youth improve their interest and achievement in science (Fadigan & Hammrich, 2004; Park et al., 2011). Out-of-school programs can offer American Indian youth more culturally relevant and STEM-related learning opportunities. As demonstrated in this study, out-of-school programs should be designed in more culturally relevant and student-centered ways in order to encourage minority youth to use their own schema of knowledge in learning science.

## VI. Implications

This study has implications for further research in designing problem-solving lesson modules using culturally relevant STEM topics for students who are from historically marginalized populations. Furthermore, we need to consider how cultural and everyday life experiences affect American Indian students' problem-solving techniques, which in turn affect our own instructional design.

First, we need to consider offering more opportunities for younger minority students. Recent research has identified large science achievement gaps at the end of 8th grade between white and racial/ethnic minority children, and between children from higher- and lower-income families. These achievement gaps begin very early in the educational career span (Morgan, Farkas, Hillemeier, & Maczuga, 2016). Thus, early exposure to, positive attitudes toward, and achievement in math and science are important factors in a student's declaration of a STEM major (Crisp, Nora, & Taggart, 2009).

Creating a teaching moment that allows students to apply their cultural and everyday life experiences is

important. We must expand the view that problem solving should be situated in a narrow context with one purpose and a few variables. For younger students such as the participants in this study, we need to consider instructional methods for presenting problem-solving tasks in meaningful ways, using students' prior knowledge and experiences, as well as the social environment, to optimize learning.

These implications also apply to Korean STEM education. As society becomes rapidly multicultural and as regional and socioeconomic gaps continue to widen, issues related to race, culture and/or socioeconomic status become important challenges in improving Korean STEM education, in terms of effectively supporting these populations. We need to differentiate instruction by using curricula that reflect the cultural values and interests of these populations and their prior knowledge and experiences. For example, we can make connections between the problem-solving tasks and knowledge and skills that regional students will need to address community challenges and needs.

A culturally relevant STEM curriculum also allows regional students in Korea to learn from a familiar community/cultural base, to develop an understanding of and pride in their community/culture, and to make contributions to their local STEM industries in the future, thereby reducing regional and socioeconomic gaps.

## 국문요약

본 연구는 북미 토착민인 인디언 학생들을 대상으로 설계된 문화 반영적 융합교육(STEM)을 이용한 문제해결 수업을 보여준다. 이 수업은 악기상을 고려한 Shelter Design 또는 피난처 설계에 관한 것이었다. 이 수업은 인디언 학생들을 대상으로 6일간 여름방학캠프 프로그램으로 적용되었으며 모든 수업은 인디언 보호구역에 있는 학교에서 실시되었다. 본 연구를 위한 데이터로는 학생들의 Shelter

Design 그림, 그림에 대한 부연 설명, 그리고 학생용 학습지였다. 데이터는 질적 분석 방법에 의해 분석되었다. 본 연구의 결과 학생들은 문화 반영적(STEM) 수업 후 STEM 지식을 더 많이 습득하였으며, Shelter Design 활동을 하는 동안 학생들의 문화적 지식과 일상생활 경험 등을 활용하여 문제를 해결하는 것으로 드러났다.

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