Curriculum Development for STEM Integration: Bridge Design on the White Earth Reservation

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ABSTRACT
To promote STEM (science, technology, engineering, and mathematics) education with American Indian students in grades 5-8, a civil engineering focused curriculum was designed through collaboration among educators, researchers, and engineers. The curriculum was created to introduce American Indian youth to career opportunities in civil engineering, various civil engineering concepts, and the role of civil engineers in the technology driven 21st century. The emphasis of the curriculum is placed on structural engineering, which is a branch of civil engineering concerned with the design and structure of buildings, bridges, and roads. The curricular activities focused on one particular structure - bridges. Through the activities the students engaged in engineering, as well as science, mathematics, and technology.

INTRODUCTION

The Education of American Indian Students
Researchers have addressed various issues regarding the education for American Indian students (e.g., Bradley, 1984; Nelson, Simonsen, & Swanson, 2003; Preston, 1991). School problems such as low enrollment and graduation rates, large percentage of absenteeism, suspension and expulsion, low achievement scores on math, science, and reading, and the high drop out rates are commonly associated with American Indian students’ education (U.S. Department of Education, National Center for Education Statistics [NCES], 2008a). The rates of absenteeism, suspension, and drop out are higher in schools that serve only or a high percentage of American Indian students. This is particularly true for students who enroll in reservation schools. Tribes have made effort to improve the education in reservation schools; however, American Indians are still behind in relation to the education that the White population has in the U.S. In 2007, approximately 44% of American Indians in the U.S. completed an undergraduate or graduate program, 36% of American Indians had a high school diploma, and 20% had no high school diploma while only 9% of Whites did not finish high school (NCES, 2008a).

Most American Indian students go to the schools in rural areas. While the majority of these schools are located far away from the urban areas, others are close to the urbanized areas. American Indian students enroll in public schools, private schools, or schools that are administered by Bureau of Indian Education. Almost 90% of the American Indian students attend public schools (U.S. Department of Education, 1991). In the 2005-2006 school year, American Indian students represented 1% of the students who enrolled public schools in the U.S and the majority of the American Indian students enrolled in public schools were in the following states: Alaska (27%), Oklahoma (19%), Montana and New Mexico (11%), and South Dakota (10%) (NCES, 2008b). In the same academic year, of all the American Indian students, only 8% were found to attend schools funded or operated by Bureau of Indian Education.

Several researchers have addressed the ways to improve the education of American Indians such as implementing culturally relevant curriculum (Preston, 1991), applying Native American pedagogy (Hankes, 1998), and training teachers to meet the particular needs of
American Indian students (Bradley, 1984). Application of culturally relevant or responsive education in American Indian students’ education is critical in improving their achievement (Bradley, 1984; Nelson-Barber & Estrin, 1995). Culturally relevant education refers to teaching academic subjects (e.g., science and mathematics) in an appropriate cultural context. It requires linking pedagogy, culture and the subjects. Demmert and Towner (2003) point out that culturally based education has six elements:

1. Recognition and use of Native American languages
2. Application of pedagogy that includes cultural characteristics and the adult-child interactions
3. Application of teaching strategies that match with the traditional culture and ways of knowing and learning
4. Use of curriculum that reflects the traditional culture and emphasizes the spirituality
5. Participation of the native community (parents and elders) in schooling.

Students bring their cultures to the classroom, and it is very vital to connect school subjects to students’ cultural values and their everyday life experiences. Nelson-Barber and Estrin (1995) suggest teachers of American Indian students teach each subject through embedding it into cultural activities. For example, the making of birch bark basket, weaving rugs, and use of beading play an important role in American Indian cultures. These activities can be used to teach geometry, number theory, and measurements. Healing plants, rice, maple syrup, and basswood are also integral part of American Indian cultures and can be used in formal science education. The curriculum that reflects American Indian students’ culture can increase students’ attitude toward the school and their academic performance (U.S. Dept. of Ed., 1991).

Teachers play an important role in student learning. NCES’s 2007-2008 school and staffing survey results show that the American Indian/Alaska Native teachers represent only 0.5% of teachers in the U.S, while in Bureau of Indian Education schools, 39% of the teachers are American Indian/Alaska Native (NCES, 2009). The data demonstrates that most American Indian students’ teachers are from a different ethnic group; they are most likely White since about 84% of the teachers are White in the U.S. (NCES, 2009).

Teachers of American Indian students should be facilitators and allow students to work on the activities or to solve the problems in any way that makes sense to students (Hankes, 1998). American Indian students’ teachers should link the disciplines that they teach to students’ existing knowledge, experiences, learning style, and culture that they bring into the classroom (More, 1989; Swisher & Deyhle, 1989). The teacher education programs should be designed to allow non-Native teachers to learn about culturally relevant pedagogy. Teachers should improve their knowledge on the norms and the values of the other cultures. It is necessary to recognize that the learning styles in cultures are different; thus, teachers should adapt their teaching methods for the students to meet their particular needs.

In addition to the cultural experiences and prior knowledge that students bring into the classroom, culturally relevant teaching also focuses on the way students learn and understand. American Indian students have different learning styles (More, 1989; Preston, 1991; Swisher & Deyhle, 1989). Their learning is dependent upon their environment, and they think in more relational styles rather than in analytic styles (Preston, 1991). In addition, they could not easily see the connection between the whole and its subcategories. Since most are visual learners, American Indian students learn best by observing their parents or elders (Pewewardy, 2002). Preston suggests that using experiential learning and cooperative learning activities can improve
these students’ problem solving abilities and can reduce their mathematics and science anxiety (Preston, 1991). Furthermore, Preston points out that workshops, after school, and weekend or summer school opportunities that emphasize hands-on activities and applications to real life situations can improve American Indian students’ attitudes toward mathematics and science. It is well documented that American Indian students demonstrate high interest and success as they participate in activity-based science programs (Zwick & Miller, 1996).

It has been addressed that parental involvement is a necessary factor for American Indian students’ achievement (NCES, 2008a; U.S. Dept. of Ed., 1991). Thus, parents of American Indian students are highly encouraged to be involved in the education of their children. However, few American Indian parents are involved in school, value education, or have high expectations for their children (NCES, 2008b). This is one of the main reasons for American Indian school failure and resistance to schooling: the clash of the culture of the parents/homes and the school. Students struggle with two cultures, and parent involvement can decrease the cultural differences between school and home (Reyhner, 1992).

The socio-economic factors also influence American Indian students’ education. Particularly, in the reservations, a large percentage of parents are unemployed, and most students do not have access to materials such as computers, books, and magazines at home (NCES, 2008). Most schools with high population of American Indian students do not have necessary equipment and facilities such as science laboratories. Developing partnerships among the community, business, industry and colleges can provide financial support to improve the schools in reservations (U.S. Dept. of Ed., 1991).

**STEM Integration into American Indian Students’ Education**

Integrating STEM into American Indian students’ education is very critical. Most American Indian students do not adequately learn science and mathematics in elementary and secondary school since the main focus is on language arts in early grades. Even though most American Indian students speak only English at home, they have limited English proficiency. The vast majority of students successfully communicate with their classmates and teachers; however, they are behind in writing and reading. The National Indian Education study results on reading and mathematics achievement scores of 4th and 8th graders show that the average scores for American Indian students are lower than non-American Indian students in the U.S. (NCES, 2008b). In 2005, the science scores of 4th, 8th, and 12th grade American Indian students were lower than White students’ scores (Grigg, Lauko, & Brockway, 2006). These findings show that American Indian students are not learning the mathematics and science needed to be successful, and therefore different strategies must be employed to engage American Indian students in STEM subjects.

The main factor that influences American Indian students’ mathematics and science achievement is the cultural differences between home and school. In schools, Western views of mathematics and science are applied to teach these disciplines and this does not reflect what American Indian students know and believe. Bringing an American Indian view of mathematics and science into the school curriculum is necessary. Thus, the Bureau of Indian Affairs, for example, developed American Indian standards for science education. The standards align with the National Science Education Standards (National Research Council, 1996). The science concepts that are in the national science education standards modified to American Indian cultures. For example, the following (Figure 1) is the physical science content standard B for grades 5-8 (U.S. Department of Interior, Bureau of Indian Affairs, 1998, p.7).
When teaching mathematics and science using effective materials such as manipulatives might help American Indian students understand science and mathematics easily. Integrating cultural stories into the instruction can be also helpful for students to learn these subjects since storytelling is an important part of their everyday lives. As Preston suggests (1991), teaching subjects through telling stories that students are familiar with can decrease American Indian students’ anxiety to the school subjects. Giving human characteristics to animals, trees, wind, and soil in the stories have found to be very effective in American Indian students’ learning (More, 1989). Another manner of helping students understand is through the use of contexts that are socially relevant to the students’ communities (Rodriguez, 1998).

One way to integrate STEM into American Indian education is teaching science and mathematics using engineering as context. Science, mathematics, and engineering can be easily embedded in culturally relevant activities. Students can employ technology while completing the activities. To make STEM more culturally relevant to American Indian students, the innovative “Reach for the Sky (RFTS)” program at the University of Minnesota was developed as a summer and after school program. RFTS serves a specific group of American Indian youth – Anishinabe – who live on the White Earth Indian Reservation in Minnesota. The program is a three-year project funded by the National Science Foundation. The curriculum that is presented in this chapter was implemented in the second year of the RFTS program. The curriculum was delivered to approximately 70 American Indian students in the after school program of the RFTS project and was implemented in a two month long period in fall 2008.

**CURRICULUM DESIGN**

The curriculum was created to introduce American Indian youth to career opportunities in civil engineering, various civil engineering concepts, and the role of civil engineers in the technology driven 21st century. The curriculum emphasizes structural engineering and the curricular activities focused on bridges. The context of this curriculum was chosen due to the social relevance to the students due to the 35W bridge collapse over the Mississippi River in Minnesota on August 01, 2007. This devastating tragedy impacted many families in Minnesota,

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**Physical Science: Content Standard B**

*As a result of activities in grades 5-8, all Indian students should develop an understanding of:*

- The principal of changes of properties in materials applied in the daily activities of early Indians, such as evidenced in the preparation of wood splints for basketry, the production of glue from the hooves of a deer, and the preparation of natural dyes.
- How energy was transferred through the use of early Indian hunting tools such as the act of throwing a spear with an atlatl.
and it brought attention to the nation’s other bridges. The media has presented massive information regarding the 35W bridge collapse and structural deficiencies of many other bridges.

The design of the curriculum is theoretically aligned with sociotransformative constructivism. Curriculum design from a constructivist perspective focuses on the social construction of learning and enables students to learn through collaboration (Hand & Treagust, 1991). Sociotransformative constructivism implies that the learning takes place with the perspectives of dialogic conversation, metacognition, reflexivity, and authentic activity (Rodriguez, 1998). The bridge building activities allowed students to actively engage in their knowledge construction as they learned the concepts through hands-on activities (constructivism). Demonstrations, computer simulations, and videos were employed to increase students’ engagement. In addition, all students were asked to keep journals, written as blogs, to reflect on their learning (metacognition). The designers of the curriculum, the authors of the chapter, created a restricted online social network with content management capabilities (Ning – http://www.ning.com/) to deliver the curriculum and allow students to have interactive experiences with technology and with the instructors and designers (dialogic conversation). Only the students, teachers, and the designers of the curriculum had access to the RFTS Ning site. The website enabled students and teachers to share curricular artifacts and their experiences with the curriculum (reflexivity). Finally, the setting is around the very socially relevant context of the bridge collapse, which allowed for discussions of ethics, beliefs, etc. related to the collapse, and what role civil engineers play, as well as the students themselves, when tragedy strikes (authentic activity).

The curriculum included six individual lesson plans, each to be completed in one to three 50 minute long class periods. Each lesson plan included a student activity worksheet that students completed at the end of the activity. In addition, lesson plans included extensive content information for the teachers to read before the instruction. When implementing the curriculum, teachers followed the detailed procedure for each activity during the classroom instruction. Lesson plans also provided options for teacher to extend the lessons. The lesson extensions required students to conduct an Internet search on the specific part of the content that was discussed in the lesson and then present the findings in the classroom. The curriculum included five main parts: exploring civil engineering, bridge construction, different types of bridges, designing the least expensive bridge, and the bridge replacement Model-Eliciting Activity (MEA).

**Exploring Civil Engineering**

In the first part of the curriculum, students explored civil engineering and gained an understanding of the engineering design process – ask, imagine, plan, create, test, improve (Museum of Science Boston, 2009). First, the students watched short video clips that explored civil engineering as a career. These video clips were uploaded onto the Ning site by the curriculum developers. Students were encouraged to search for different video clips on the Internet and to add them onto the Ning site.

Students then discussed different types of civil engineering projects found in their community and how to become a civil engineer. There were two purposes in this: (1) to help the students connect the content of the curriculum to their everyday lives, and (2) to encourage the students to consider engineering as a career. Following these introductory activities, students engaged in deep discussions about the 35W bridge collapse. This context connects activities in the Summer 2008 RFTS program to the curriculum in the after-school program in Fall 2008. During the summer program, the students visited the new 35W bridge construction site to
observe the new bridge construction. Civil engineers from the company building the new 35W bridge gave presentations about the structure of the old and new bridge to the students. This connection and the resulting content were revisited in Fall 2008. Through analyzing the 35W bridge collapse and the design of the new bridge, students increased their knowledge about the different bridge structures and also engaged in the curriculum activities. When the first part of the curriculum was finished, students wrote short essays describing a career in civil engineering. They posted their essays on the Ning site. The curriculum developers provided feedback to students on their essay.

**Bridge Construction**

In the second part of the curriculum, students built model bridges following engineering processes. These activities were based on the bridge curriculum in the *Design It! Series* (Hutchison, McCulloch, & Zubrowski, 2002). Through building paper bridges, students experienced bridge structure as they learned about science concepts such as balance and forces (e.g., tension, compression, torsion, shear, and flexure). At this stage, teachers used various demonstrations with paper towel tubes to help students understand these abstract concepts. They then discussed how different forces act when the length of a beam and shape (e.g., round, square, etc.) of columns changed. Students looked at the various pictures on the Ning site to see bridges with different types of columns. Students then built beams and columns from copy paper with the goal of creating the strongest bridges (Figure 2), and they participated in a small competition where they put weights on their bridges to find the bridge formation that is most structurally stable. After the competition teachers provided enough time for students to redesign their bridges to make them stronger.

![Figure 2: Students building paper bridge](image)

**Different Types of Bridges**

The third part of the curriculum focused on different types of bridges (beam, truss, arch, suspension, and cable-stayed) and how different types of forces act on each type of bridge. Groups of three to four students built all five types of bridges from the K’NEX™ Education set *Bridges: Introduction to Structures*. The students tested their bridges (Figure 3) by putting weights on them to find how strong they were and what forces were acting on them. When they built all five types of bridges they discussed the similarities and differences among different types of bridges. During that time, teachers showed pictures of different types of well-known bridges and asked questions such as, “What factors might engineers consider while designing these bridges? What were these bridges designed for? What are the main structural differences among these bridges?”
Designing the Least Expensive Bridge

In the fourth part of the curriculum, students used the West Point Bridge Design (WPBD) Software 2007. It is free software and can be downloaded from http://bridgecontest.usma.edu/. The software allows students to build various types of truss bridges (e.g., through truss and deck truss) and test their designs. Figure 4 shows a screen shot of a truss bridge design in WPBD. Students engaged in the engineering design process by utilizing this bridge building software that has a real life estimator for cost analysis and structural analysis. Groups of two students designed their truss bridges. Students first chose the possible site configurations such as abutments, deck, span, and excavation for their bridge. They then decided what type of truss bridge they would use in their design. Next, they built their structural model. When students drew joints and connected the joints they completed their preliminary design. The next step was for the students to choose the material (e.g., carbon steel), cross section (e.g., solid bar), and size of the material (e.g., 120 mm). Their choices of those variables affected the cost and the stability of their bridge design. Students attempted to design the least expensive bridge, but they were supposed to build a design that was strong enough to carry the traffic loads which was described in the program. When students completed the load test, they found whether or not their bridge design failed the load test. If their bridge design failed, they increased the strength of the members of their bridge while considering the cost. When all groups completed their optimal bridge design, they presented their design to the class.


Bridge Replacement Model-Eliciting Activity

The final part of the curriculum had students engage in a Model Eliciting Activity (MEA), which is a problem-based design activity focusing on solving real world problems (Diefes-Dux, Moore, Follman, Imbrie, & Zawojewski, 2005; Moore, 2008). Students worked in groups of 3 to 4 to create a procedure to choose the type of bridge design to replace a bridge, which is structurally similar to the 35W bridge and has structural deficiencies. Students made construction decisions, developed skills in critical thinking and teamwork, and experienced the engineering design cycle (see appendix for more information about the bridge replacement MEA).

TEACHER TRAINING

The teachers of the after school program were trained on how to deliver the curricular unit by the curriculum designers. The curriculum was implemented in three school sites with two teachers collaboratively teaching at each site. Six teachers participated in the trainings. During the two four-hour long trainings, teachers as students experienced all the curricular activities (split between the two trainings). In addition, teachers learned how to use the RFTS Ning site by designing their own blogs, creating discussion boards, and uploading pictures and videos. After the completion of the first training, teachers started to implement the curriculum in their schools. Teachers regularly communicated with the curriculum designers through the Ning site during curriculum implementation. The necessary lesson plan modifications were discussed and changes were made. Some teachers asked students to complete extra activities such as an internet search on the class material. All these plans were discussed among teachers and the curriculum developers before being implemented in the classroom. Teachers also informed the curriculum developers of the effectiveness of the lessons on the level of student engagement and time constraints.

EVALUATION OF THE CURRICULUM

To investigate the effectiveness of the curriculum on enhancing American Indian students’ interest and understanding of civil engineering concepts, a research study was designed. A mixed-method research methodology was employed in the study (Creswell & Clark, 2007). Various data collection instruments were used: students’ pre- and post-tests, blogs, and MEA procedures, and teachers’ reflection journals. Clements’s Curriculum Research Framework (CRF) (2007) was used to structure this curriculum study development. Clements defines curriculum as “a specific set of instructional materials that order content in order to support pK-12 classroom instruction” (p. 36). Using Clements’ framework, the research followed a three-phase process: (1) use existing research that allow the curriculum development team to apply what is already known to the curricular modules, (2) revise curricular modules in accordance with models of children's thinking and learning within the specific content domain, and (3) conduct formative and summative evaluations in classroom settings. Stages 1 and 2 were completed prior to the implementation of the curriculum reported in this paper. The curriculum developers used prior research and pilot testing as our means to complete these stages. The evaluation of the curriculum is the focus of the research here. Stage 3 is comprised of formative research and summative research. This chapter aims to report the formative research of stage 3. Future research will report on the summative research on this curriculum.
The qualitative data is reported in the form of excerpts of student classroom artifacts and teacher responses to reflection questions. This data is being used in the formative stages of the research to allow the project staff to revise the curriculum. The quantitative research is a paired t-test (Muijs, 2004) to determine if the students’ pre- and post-test data differs significantly. Here, a \( p = 0.05 \) cutoff level of significance was used to determine statistical significance.

Of the 64 students, 27 completed both pre- and post-tests, 30 students completed only the pre-test and 7 students completed only the post-test. The pre-post content test was developed based on the content being taught in the curriculum. It covered structural engineering content including structural similarities and differences in five different types of bridges (i.e., beam, arch, truss, suspension, and cable) and strengths and weaknesses of these different bridge structures. In addition, the test was designed to capture students’ understanding of science and mathematics concepts related to structural engineering. The science concepts in the test included the forces that act on a bridge and the mathematics concepts focused on geometrical shapes of columns and the effect of bridge pier shape on the stability of bridges. The pre- and post- tests were equivalent and included same number of true false questions, matching questions, fill in the blank questions, and open ended questions. The pre-post test scores of the students were graded based upon percentage of correct answer. Mean score for the pre-test is 29 and mean score for the post-test is 51 out of a total of 100.

The hypothesis test is as follows:

\[ H_0: \text{The means of the pre- and post-tests are equivalent.} \]
\[ H_a: \text{The mean post-test is greater than the mean of the pre-test.} \]

Rejection of the null hypothesis comes when the differences between the means are statistically significant (\( p < 0.05 \)). This is a paired test of significance. The scores of the 27 students who completed the pre- and post-test were compared. Table 1 shows the results of the paired t-test. The null hypothesis was rejected (\( p < 0.0001 \)) in favor of the alternative hypothesis showing a significant difference between pre- and post-test scores. The quantitative data analysis demonstrates that the curriculum has positive impacts on the students.

<table>
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<th>Variable</th>
<th>N</th>
<th>Mean</th>
<th>StDev</th>
<th>SE Mean</th>
<th>T</th>
<th>P</th>
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<tbody>
<tr>
<td>Diff.</td>
<td>27</td>
<td>22.98</td>
<td>432.19</td>
<td>84.76</td>
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The students’ blog entries provided information on their level of engagement in activities. Most students indicated that they enjoyed building bridges. Before receiving the curriculum, almost all students could not explain the job requirements of civil engineers, but at the end of curriculum implementation, each student could provide a reasonable explanation of the roles and duties of civil engineers in society. Some sample responses are:

“Civil engineers design buildings, bridges, and roads”

“They build bridges, roads, tunnels, and subways.”

“I think that civil engineers build buildings. They built the Golden Gate Bridge. They also built some of the tallest skyscrapers, including the Empire State Building!”

“Civil Engineers are people who design, work, (of course…) and also they plan. They fix a lot of things, like: bridges, (most common) buildings also. I also think civil engineers
are very interesting now that I know about them...At first I didn't even know about civil Engineers.”

The following quotes demonstrate student interest in becoming engineers:

“I liked looking at pictures and watching videos of civil engineers and bridges, I think engineering is about building cool stuff”

“I want to be an engineer.”

The analysis of MEA responses shows that students’ increased their knowledge about bridge structures. The examination of MEA responses provided information about how well the students understand the concepts that were presented through the curriculum. Students’ responses demonstrate that students thought critically, collaborated, analyzed, and synthesized given information, and used that information to solve the real engineering problem. In their responses, students specifically explained what particular type of bridge they would choose to replace the bridge that is given in the MEA. Examples of student answers are below (including Figure 5).

“I think an arch bridge would work because it lasts a long time and it is built for long distances. The arch would be better because the bridge is made out of stone and a lot of stone is found around Minnesota. But the problem is that the arch is hard to build and cost a lot. They look fun to build.”

“I want build a truss because a truss bridge is a strong bridge it stand strong wind not like suspension bridge. The truss bridge’s span is going to be around 2,000feet long at least.”

“I would like to build the arch bridge. I want it to be kind of like 10th Ave. bridge, 2175 feet, 101 feet below and it would maybe as much as the 10th Ave bridge. I want it to have four lanes. It would difficult to build though. You could use the rocks from Minnesota. It would be beautiful and last a long time like the 10th Ave bridge did. Arch bridges are very strong. It has materials that are strong such as stone, cast iron, timber, and steel. It will be very helpful for all the people that live in St Cloud. I think it will cost about nine or ten million dollars. The 10th Ave. bridge cost about that much.”

To: Mn/Dot

From: Engineering team

We chose the truss bridge because we looked at a similar bridge in Dubuque, Iowa. The Iowa bridge had two lanes and the Iowa bridge was twice the size. The cost of the Iowa bridge was 2.5 million at 2000ft. Our bridge needs 5foot sidewalks but it is only half of the size. We felt that the Iowa bridge has lasted over 100 years. It must be a strong safe bridge. We would estimate the bridge cost 1.75 million dollars with the two lanes and the 5 foot sidewalks.

Procedure:
1. The first thing would be the cost of all the bridges
2. We thought it would be safe and strong
3. How much weight can support the bridges

Figure 5. One team’s solution to the bridge replacement MEA.
Teacher’s reflection papers provided valuable information regarding the effectiveness of the curriculum. Some teacher reflections on the curriculum are:

“Getting our students to think about engineering as a career is great. The understanding that engineers are problem solvers is a wonderful lesson all by itself. They enjoyed exploring what civil engineers do too.”

“All of the students were interested in the topic of bridges. All of the students gained from the curriculum…They all enjoyed the time on the computers and the time building with the K’NEX. The objectives of the bridge building activities were all met but at very different levels for different student.”

“It’s a great curriculum. It gives kids a lot of great knowledge and experiences. It is a great introduction to engineering.”

“I felt that the students were engaged most of the time. They had a lot of fun when we started the curriculum…”

“I thought that the curriculum was fun and the kids had a good time building the bridges. I was disappointed that the computer program [WPBD] did not work at our school.”

**CHALLENGES FACED DURING THE IMPLEMENTATION**

Originally, the curriculum was designed to implement in a two and a half week long period – one hour of instruction every school day. However, in the after school program students met four days a week for one and a half hours. The curriculum could not be completed in the planned time period mainly because of the time constraints put on teachers for other unrelated parts of the after school program and because of computer related issues that teachers experienced. Curriculum activities required regular computer use; however, the access to the computer labs in schools was challenging. Because it is an after school program, little technological help was available to teachers to overcome computer-related problems. For example, the WPBD software works only on PC. Two of the schools have only Macs so cross-platform software programs needed to be downloaded to these computers. While teachers made the extra effort to be able use the software program in the program, one school was not able to get the WPBD software to work.

Creating a sustainable community in the RFTS Ning site was also a challenge that the curriculum designers faced. At the beginning of the curriculum implementation, the quality of students’ blog entries was below expectations. Instead of using Ning to give responses to the content related questions or participating in the content focused discussions, students used Ning to socialize with their classmates. Thus, teachers strongly encouraged students to be reflective in their learning process and to participate in online discussions. Students gradually became more interested in forums and discussions. However, some students found it difficult to engage in the forums or discussions since they had under-developed writing and reading skills.

Attendance was another challenge that teachers faced while implementing the curriculum. Approximately one fifth of the students attended the program for the full duration of the curriculum implementation. The rest of the students came to the program at various times. Thus, the vast majority of the students did not post blogs regularly or complete all of the parts of the curriculum.
A final challenge revolved around the location of the curriculum developers and the schools. Since the school sites and the university are far away from each other, the university educators could not make as many observations or provide as much on-site help as was needed or wanted. However, teacher training, detailed lesson plans, and continuous communication between teachers and the curriculum designers allowed teachers to successfully implement the curriculum.

EVIDENCE OF SUSTAINED LEARNING

This curriculum was implemented in the after school portion of the RFTS program. The summer program is separate from the after school program, so it is important to note that twelve of the students who received the bridge curriculum in the RFTS afterschool program in fall 2008 also attended the summer school in summer 2009. Like the afterschool program, the summer school program aims to increase students’ knowledge and understanding of STEM and increase their interest in STEM careers. The first day of the 2009 summer school program, all students completed a “draw an engineer test” (Knight & Cunningham, 2004). In this activity, students showed their knowledge about engineers through their drawings. They also provided written responses to the following question: “What do engineers do when they are working?” The analysis of students’ drawings shows that students who participated in the afterschool program have well-developed understanding of engineering, particularly civil engineering. From twelve students who attended the afterschool program, ten of them drew a civil engineer; the remaining two drew a mechanical engineer who fixes cars or trains. Students who drew a civil engineer used the words “make”, “build” and “design” to explain what civil engineers do. The following (Figures 6 and 7) are the images of the drawings of two students and their responses to the question, “What do engineers do when they are working?”

CONCLUSION

Given the growing emphasis on STEM education, this curriculum provides valuable information for university educators, researchers, and K-12 educators interested in the best practices in STEM education. The curriculum sheds new light on the effective design and
implementation of integrated science, technology, engineering, and mathematics education curricula. To enhance STEM education in K-12 in diverse settings, a strong emphasis should be given to integrating engineering with other STEM disciplines in a contextual manner.

As evidenced by the data, students learned how to apply mathematics, science, and technology to engineering problems through engaging with the curriculum activities. The curriculum activities greatly increased students’ knowledge and level of interest in engineering as shown in students’ pre- and post-test results and blog entries. Further, it was found that hands-on, inquiry-based activities enhanced students’ motivation. Thus, to increase the knowledge and skills of American Indian students in STEM disciplines teachers should apply student-centered instruction based on sociotransformative constructivism.

The bridge curriculum was particularly designed for an after school program, but with modifications, it can be easily implemented in a regular school program. As a next step, the designers of the curriculum plan to formalize the curriculum and implement it in an engineering education focused inner city school.

ACKNOWLEDGMENT

This material is based upon work supported by the National Science Foundation under Grant No. 0737565 and Grant No. 0717529.

REFERENCES


Appendix
Model Eliciting Activity-Part A
Bridge Replacement-Individual Activity

Read the following information and individually answer the questions that follow.

35W Bridge Collapse
Background material adapted from Mn/Dot Bridge website (http://www.dot.state.mn.us/bridge/)

The Interstate 35W Mississippi River Bridge in Minneapolis collapsed on August 1, 2007. The eight lane bridge was Minnesota’s busiest, carrying 140,000 vehicles a day. This deck steel truss bridge was 1,907 feet long and had 14 spans. It was open to traffic in 1967 and expected to be reconstructed in 2020-2025. The bridge was inspected every two years until 1993; after that it was inspected every year.

Starting in 1997, deficiencies were demonstrated in inspection reports. Mn/Dot attempted to improve the condition of the bridge through bridge span rehabilitations. Furthermore, in 2001 Mn/Dot worked with civil engineers from University of Minnesota to evaluate the fatigue stress within the truss. Following the field tests, the civil engineers recommended that fatigue cracking was not expected to be a problem in the truss but reported that some critical locations of the trusses had high stress and some girders were distorted. The bridge’s last inspection was completed in June 15, 2006. As a result of comprehensive analysis on fatigue and fracture structure recommended supporting the critical 52 truss members.

During the 35W bridge collapse, 13 people were killed and more than 100 injured. The investigations on the collapsed bridge continue. Mn/Dot has investigated every single detail to find what caused the bridge collapse. It has been considered that gusset plates in the center span and the extra weight from construction may have contributed to the tragedy. The gusset plates are steel plates that tie steel beams together on a bridge. These are a very important structural component of truss bridges. However, it should be also considered that gusset plates are not the only structural components in truss bridges; other critical parts of the bridge might have deficiencies. In addition, extra weight may not be a main factor for the bridge collapse since the bridge had less than its usual traffic at the time of the collapse. Half of the lanes were closed for the repair when the bridge failed.

Individually:
• Watch the video of 35 W bridge collapse from http://www.youtube.com/watch?v=osocGiofdvc
  Or go to http://reachforthesky0809.ning.com
• Generate a list of factors you believe are involved in the 35W bridge collapse.
• Generate a list of factors that you need to consider when designing a bridge.
• Once you have finished your individual response, request the memo from Mn/Dot. Read the memo individually and then let your instructor know that you are ready to proceed.
INTERNAL MEMO

To: Engineering Team
From: Mn/Dot
Re: Bridge Design

After the 35W bridge collapse, Mn/Dot has focused attention on the condition of other bridges in Minnesota. Mn/Dot conducted recent inspections on bridges in the Minnesota and found that there are 1,907 bridges that are structurally deficient. As a result of recent inspections, Mn/Dot shut down another bridge in March 2008. Originally, the bridge was scheduled for replacement in 2015, but Mn/Dot inspectors found critical deficiencies during the inspection. The bridge has a similar design configuration as 35W Bridge and it is located over the Mississippi River in St Cloud. Mn/Dot plans to replace the bridge soon. The new bridge will be located in the same place as the old one. It will carry a highway and run east-west. The length of the bridge will be approximately 900 feet. The bridge deck should have two lanes and should also have 5 ft wide sidewalks along both sides of the bridge.

Starting with the St Cloud Bridge, Mn/Dot will replace many of the bridges that have been found to be structurally deficient. Because so many bridges are going to be replaced, Mn/Dot needs a procedure for comparing different type of bridges and choosing the right type of bridge to build across each span. Mn/Dot is asking you to create this procedure. First, your team should decide on the least expensive and safest bridge to replace the St. Cloud Bridge. Pay attention to how you made this decision because we also need you to create a procedure to make the same type of decision in other locations around Minnesota. Mn/Dot will use your procedure to replace the St Cloud Bridge and then other bridges. Please find the enclosed information regarding the types of bridges that Mn/Dot plans to build—truss bridge, arch bridge, suspension bridge, and cable-stayed bridge. In addition to the information about the major types of bridges, Mn/Dot also has provided you two examples of four types of bridge in the U.S. You may need to use this information as a starting point to determine your procedure for selecting the new bridge design. Please respond in a letter to Mn/Dot explaining which bridge is right for the St. Cloud span and why you chose it, and provide them with a method to make the decision of which type of bridge to use to replace any bridge in Minnesota.

Thank you.

Peggy Abrams
Model Eliciting Activity- Part B
Bridge Replacement- Team Activity

- Read each team member’s individual list of factors that need to be considered when designing a bridge.
- Reread the Memo as a team.
- Write the body of a memo to Peggy Abrams at Mn/Dot that includes:
  - A clear explanation of what type of bridge you decided to build in St. Cloud and why you made that decision.
  - A detailed explanation of your team’s general procedure for choosing the best bridge type to build across any span and indicate how Mn/Dot can use this procedure to replace other bridges in Minnesota.
### Table 1: Different Types of Bridges

<table>
<thead>
<tr>
<th>Bridge Type</th>
<th>Advantages</th>
<th>Disadvantages</th>
<th>Span range</th>
<th>Material</th>
<th>Design Effort</th>
</tr>
</thead>
</table>
| **Truss bridge**      | -Strong and rigid framework  
                       -Work well with most applications                                        | -Cannot be used in curves  
                       -Expensive materials needed                                               | Short to medium | Iron, steel, concrete                | Low           |
| **Arch bridge**       | -Aesthetic  
                       -Used for longer bridges with curves  
                       -Long life time  
                       -Very strong                                                           | -Abutments are under compression  
                       -Long span arches are most difficult to construct  
                       -Relatively expensive                                                    | Short to long    | Stone, cast iron, timber, steel     | Medium        |
| **Suspension bridge** | -Light and flexible  
                       -Aesthetic                                                               | -Wind is always a concern  
                       -Expensive to build                                                       | Long (up to 7,000 feet) | Steel rope and concrete              | High          |
| **Cable-stayed bridge** | -Fast to build  
                       -Aesthetic                                                               | -Stability of cables need to be considered for long span bridges          | Medium (500-2,800 feet) | Steel rope and concrete              | High          |
Table 2: Examples of four major types of bridges

<table>
<thead>
<tr>
<th>Bridge Name</th>
<th>Location</th>
<th>Bridge Type</th>
<th>Total length</th>
<th>Clearance below</th>
<th>Lanes</th>
<th>Constructability</th>
<th>Life time</th>
<th>Cost (Present value)</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Hennepin Ave Bridge</em></td>
<td>Over Mississippi (Metro area)</td>
<td>Suspension bridge</td>
<td>1037 feet</td>
<td>37 feet</td>
<td>6</td>
<td>Easy</td>
<td>Fairly long (Built in 1990)</td>
<td>$100 million</td>
</tr>
<tr>
<td><em>Golden Gate Bridge</em></td>
<td>San Francisco, CA</td>
<td>Suspension bridge</td>
<td>8,981 feet</td>
<td>220 feet</td>
<td>6</td>
<td>Difficult</td>
<td>Fairly long (Built in 1937)</td>
<td>$212 million</td>
</tr>
<tr>
<td><em>10th Ave Bridge</em></td>
<td>Over Mississippi (Metro area)</td>
<td>Arch bridge</td>
<td>2175 feet</td>
<td>101 feet</td>
<td>4</td>
<td>Difficult</td>
<td>Long (Built in 1929)</td>
<td>$9 million</td>
</tr>
<tr>
<td><em>Stone Arch Bridge</em></td>
<td>Over Mississippi (Metro Area)</td>
<td>Arch bridge</td>
<td>2100 Feet</td>
<td>24.4 feet</td>
<td></td>
<td>Difficult</td>
<td>Long (Built in 1883)</td>
<td>$15 million</td>
</tr>
<tr>
<td><em>Greenway Bridge</em></td>
<td>Minneapolis, MN-55, Light Rail Line</td>
<td>Cable-stayed bridge</td>
<td>2,200 feet</td>
<td>20 to 27 feet</td>
<td></td>
<td>Easy</td>
<td>Fairly long (Built in 2007)</td>
<td>$5.2 million</td>
</tr>
<tr>
<td><em>Arthur Ravenel Jr. Bridge</em></td>
<td>South Carolina, crosses Cooper River</td>
<td>Cable-stayed bridge</td>
<td>13,200 feet</td>
<td>186 feet</td>
<td>8</td>
<td>Easy</td>
<td>Fairly long (Built in 1929)</td>
<td>$62 million</td>
</tr>
<tr>
<td><em>John E. Mathews Bridge</em></td>
<td>Florida, crosses St. Johns River</td>
<td>Truss bridge</td>
<td>7736 feet</td>
<td>152 feet</td>
<td>4</td>
<td>Difficult</td>
<td>Short (Built in 1953)</td>
<td>$65 million</td>
</tr>
<tr>
<td><em>Eagle Point Bridge</em></td>
<td>Iowa</td>
<td>Truss bridge</td>
<td>2,000 Feet</td>
<td>70 feet</td>
<td>2</td>
<td>Difficult</td>
<td>Short (Built in 1902)</td>
<td>$2.5 million</td>
</tr>
</tbody>
</table>