Session No: 2270

STRENGTHENING NATIVE AMERICAN PATHWAYS TO SCIENCE AND ENGINEERING EDUCATION

G. Padmanabhan, Wei Lin, Robert Pieri, Floyd Patterson, Sharon Cobb
North Dakota State University

Carol Davis
Turtle Mountain Community College

Abstract

Native American population is highly underrepresented in mathematics, science, and engineering professions. In order to increase Native American participation in MSE professions, their pathways to science and engineering education need to be strengthened. Native American high school students in the Reservations need to be nurtured, motivated and encouraged to pursue higher education in MSE disciplines. The College of Engineering and Architecture of North Dakota State University and the five Tribally Controlled Community Colleges in the State of North Dakota are currently working on a multi-year collaborative project to increase the number of Native American students pursuing college education in mathematics, science, and engineering disciplines. Motivating and encouraging the high and junior high students from the five Reservations in the State to pursue college education in engineering is one of the major objectives of the project. Currently in its third year, the project is engaging groups of high and junior high students from three of the five sites. The project started with one tribal site in the first year and increased one tribal site a year. At the end of the fifth year we hope to have all of the five sites participating in the activities. The activities include a series of one-day weekend academic sessions, one per month through the academic year, and a two-week summer camp at each tribal site. The topics were selected, and lesson plans developed, and presented collaboratively by NDSU faculty, TCCC faculty, and Reservation high school teachers. The students were presented practical day-to-day problems involving simple math, physics, chemistry, biology and engineering in an informal and friendly atmosphere requiring them to think, analyze and seek solutions. Each session included an introduction of the topic, a talk by a community representative connecting the topic to the cultural background of the students, common applications of the topic in day-to day life, background material on mathematics, science, and engineering, hands-on activities, and presentation of results by the students. Because of the vast distances and multiple sites involved, part of the academic activities were conducted in a distance-education mode. The success of the weekend academies was evident by the fact that most students who attended the first academy remained in the program for all of the academies through the year and continued for the summer camp.

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I. Introduction

Native American (NA) population is highly underrepresented in mathematics, science, and engineering (MSE) professions. North Dakota has a sizeable NA population in its five Reservations. Though there are five Tribally Controlled Community Colleges in the State striving hard to create higher education opportunities for NA students, there is concern with the low numbers of students who attempt MSE careers. There is a significant need to address the academic preparation of Native American high school students in mathematics and science to motivate and enable them to pursue college education in engineering. The possible pathways students from high schools may take in the pursuit of their careers are shown in Figure 1. Engineering educators and professionals strive hard to increase the flow of students along the Paths A and C. Many different activities are designed and delivered by engineering educators to attract and recruit high school students to college education in engineering. Activities may take place at all the nodes along the pathways facilitating easy movement along Paths A and C. Obviously the pathways need to be strengthened to make them easily negotiable and enduring. As the only 4-year land grant institution in the State, North Dakota State University (NDSU) is keenly aware of this situation. The NDSU College of Engineering and Architecture and the five Tribally Controlled Community Colleges (TCCC) in the State of North Dakota are currently working on a multi-year collaborative project to increase the number of NA-students enrolling to pursue college education in mathematics, science, and engineering disciplines. Currently the project is in its third year. Details of the proposal are reported in the Proceedings of the 2000 American Society for Engineering Education Annual Conference[1]. Activities for the 5-year proposal period focus on attracting Reservation high school students to the tribal colleges, retaining them through the college, facilitating their smooth transfer to the university, and motivating them for graduate studies in MSE disciplines. Only high school activities are described in this paper. The high school component is designed to attract, recruit, and prepare Native American students from the Reservation high schools for entry into tribally controlled colleges. Reservation high schools do not offer complete pre-college math and science experiences due to remoteness, inadequate facilities, and limited staff. It is essential to offer additional math and science exposure to these students to attract and prepare them for math, science and engineering careers. Therefore, summer camps and a series of 1-day weekend academic sessions were proposed at each of the TCCC locations for the benefit of students from the high schools feeding the colleges. Both juniors and seniors were included for participation in these activities. The descriptions of these activities follow.

II. Sunday Academy

Many of the activities currently used for attracting and recruiting students to engineering programs are sporadic. Though these activities are adequate for informational purposes, more sustained activities are necessary to cultivate a desire in the students for pursuing a college education in engineering. The activity should be spread through the year providing opportunities for the students to develop skills such as problem solving and decision-making required for successful completion of an engineering curriculum. A cohesive program spread throughout the year rather than sporadic events need to be used. Sunday academies are examples of such activities.

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It is important to provide high school students information on science and engineering disciplines, applications, and skills necessary to become an engineer. Opportunities need to be provided for them to develop a taste for engineering. Problem-solving and decision-making abilities are prerequisites for completing a mathematics/science-based program such as an engineering degree[2, 3]. Solving real-life open-ended engineering problems involves integration of mathematics, science and engineering principles. One of the difficulties experienced by students entering college level engineering programs is their inability to connect mathematics and other basic sciences to engineering problem solving. The activities need to be designed to relate mathematics and other sciences to engineering with carefully selected examples. The instructors may introduce mathematics, physics, chemistry, biology, geology, and computers, all in engineering contexts. Opportunities must be provided for the high school students to develop these skills in order for them to be attracted to science and engineering careers. They need to be shown how engineers use mathematics and science to solve real world problems. While there is no way of disregarding the need for knowledge of mathematics and sciences to pursue engineering careers, it is important to emphasize that it can be fun to learn mathematics and sciences in an engineering context. Such demonstrations will motivate students to consider careers in science and engineering

Our Model

Because of the remoteness of the Reservation high schools from the University and involvement of multiple sites a combination of 'distance education' and 'direct contact' modes of delivery were used. An Interactive Video Network (IVN) connects North Dakota State University and the TCCCs in the State. The IVN provided the capability of showing video taped demonstrations and commercially available educational videos on various topics from the host site to other participating sites. It also helped the faculty at the host site to evaluate the presentations of results by the students from other TCCC sites. The place of occurrence and flow of activities of academy sessions for the case of a single receiving site are shown in Figure 2.

The activity involved community college and university faculty and high school teachers from conception to delivery so as to provide the most important opportunity for communication among the engineering faculty and high school teachers. High school teachers gained an understanding and expertise to properly prepare the students for college education in science and engineering. The faculty became familiar with what is being taught and what is lacking in the instruction at the high school level to improve motivation of students to take up science and engineering careers.

The overall objective of the academy sessions is to generate among the high school students interest in mathematics, science and engineering and to attract them to pursue college education in engineering. On completion, the academy activities are expected to generate in the attendees

1. an interest to pursue college education in science or engineering,
2. an awareness of the science and engineering professions in general and career prospects in science and engineering,
3. an awareness of skills necessary for problem solving, and
4. an understanding of the importance of mathematics and science in engineering.

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In order for the Sunday academy sessions to be successful, the participating high schools must make a strong commitment to participate in the activities. The school administrators and the parents of the high school students were informed about the format and contents of the academy sessions through flyers. For each academic year, the flyers were sent out in the preceding summer. Since this is an activity designed for attracting students to science and engineering disciplines and for helping them to develop problem-solving skills, no specific criteria for selection were prescribed. An interest and curiosity toward science and engineering was the only pre-requisites to participate. A brochure/application form for the academy was developed and distributed to career counselors of the targeted schools.

The topics for the academy sessions were selected after detailed discussions with the community college faculty and high school teachers by the NDSU faculty. The NDSU team consisted of faculty from the departments of Mathematics, Physics, Chemistry, Civil Engineering, Mechanical Engineering, and Electrical Engineering. A two-day workshop for the community college faculty and high school teachers was organized at NDSU each year to brainstorm and develop details of lesson plans for each topic and to work out the logistics for hands-on activities for the next year. The input from the high school teachers was extremely beneficial to weed out the topics already covered by them in some detail and to decide at which level the topics were to be presented even if they had covered them in school to some degree. Also we had regular pre and post meetings throughout the year to discuss, revise, and review each session.

Topics were selected based on the following criteria:

1. Must be exciting to students
2. Must have interesting applications in industry or day-to-day life
3. Must have reasonable science and/or mathematics content at the appropriate level
4. Must be able to provide doable hands-on activities within a time frame of a few hours

The topics used for Sunday Academy in the last three years of the project are given in Table 1.

A Typical Session

In each session the problem for the day was introduced to the Reservation high school students from North Dakota State University over the IVN. The problem description, background principles in terms of mathematics, science, and/or engineering, application to real life processes and products, and the questions to be answered were included in the presentation. Also a talk by a community representative connecting the topic to the cultural background of the students was included in each session. The cultural connection of the topic particularly interested the students. For example, in the session on the topic of buoyancy a NA speaker talked about the role canoes played in the early NA transportation and migration. The IVN was switched off after the introduction of the topic and problem. Two Tribal College faculty members and two high school teachers supervised the hands-on activities of the students at each TCCC site. Also available at each site were at least one NDSU faculty for guidance. At the end of the session, the students came on IVN to present and discuss their solutions. In each session faculty spent sufficient time

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with students in preparing them for presentation. Help was provided to prepare figures, tables and graphs for presentation. Sufficient time was set apart for questions and feedback during presentation. At the end of the session a simple questionnaire was distributed for surveying the students for their evaluation of the session. A separate questionnaire was used to get the feedback from the high school teachers.

Table 1. Schedule of Academy Topics

Session Topics	Date
Height and Volume of Water Tan	10/10/99
Science of Pizza Making	11/14/99
Sound and Music	12/12/99
Floating and Sinking	01/09/00
Shadows and Reflections	02/13/00
Rockets and Forces	03/12/00
Science of Ice cream Making	04/09/00
Life in Water	05/14/00
A swingin' good time (pendulum)	10/22/00
Methods of moving heavy objects	11/12/00
Ciphers and codes	12/10/00
Water pressure and flow rate	01/14/01
Algorithms and computers	02/11/01
Chocolate: "Food of the Gods"	03/11/01
Electricity and Magnets	04/29/01
Orienteering	09/23/01
Bridges	10/28/01
Lenses	11/18/01
Magic with Chemistry	12/16/01
Gas Pressure	01/27/02
Waves	02/24/02
Hands-on Plastics	03/24/02

Student Activities

Students worked in groups of three or four on the assigned hands-on activities with guidance from the designated community college faculty and high school teachers. The work consisted of gathering data from experiments, recording them properly in tabular form, computing required results, and preparing graphs and other presentation material. Each group made a formal presentation of the experimental procedure and results to the high school teachers, and the college and university faculty. Each presentation included time for questions and answers. Students maintained a journal of all the work they did in all of the academy sessions.

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Evaluation

At the end of each session a questionnaire was distributed to the students to get their evaluation of the session. A separate questionnaire was distributed to the college faculty and the high school teachers. The feedback from the students, teachers, and faculty was helpful in improving later sessions. Also the university faculty met regularly before each session to fine-tune the lesson plan and after each session to review and improve later sessions.

III. Summer Camps

Summer camps of 2-week duration were conducted for high school students at each tribal site to help with their transition to college education. Reservation high school teachers along with faculty from NDSU and TCCCs developed lesson plans and conducted the sessions. Special emphasis was placed on topics involving interesting hands-on activities. Also included were industrial site visits. Another aspect was introducing the NDSU faculty to the tribal culture of the Native American students so the instructors are sensitive to the tribal backgrounds of the students. The camp provided an opportunity for discussions among the faculty and high school teachers on ways to improve high school curricula to accommodate the goals of students seeking careers in mathematics, science and engineering. The summer camps ended with poster displays of the results of the projects that the students worked.

The summer camp sessions were designed with the following objectives:

1. Create in the high school students an interest in the fields of mathematics, science, and engineering
2. Improve understanding of the importance of math, basic science and engineering principles
3. Improve creativity and problem solving ability of participants to solve engineering problems by applying science and mathematics principles
4. Develop technical communication (presentation and writing) skills
5. Develop skills for conceiving and conducting experiments and for interpreting results

The criteria used for the selection are given below and the topics used are given in Table 2.

1. Should be interesting enough to attract students to explore MSE fields
2. Should emphasize the need to understand fundamental concepts in MSE disciplines for problem-solving
3. Should emphasize the need to develop problem-solving ability
4. Should have easily recognizable industrial and/or real-life applications
5. Should be able to cover all aspects in the available time (4 hrs) and with the available resources
6. Should be amenable for generating hands-on activities and team work
7. Should be able to generate technical presentations by students

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Table 2. Summer Camp Topics

Summer 2000	Summer 2001
Platonic Solids	Rubber Band Powered Airplanes
Tree Measurement	Flight
Probability in Gaming	Computers, Numbers, and Logic
Fish Sampling	Bottle Rockets
What is pH?	Chemical Solubility
Water Treatment	Classifying Fingerprints
Life in Water	Candy and Crystallization
Heat and Conservation	Mousetrap Mechanics
Refraction and Light	Scientific Software

IV. General Strategy for Lesson Delivery

- If appropriate give a general overview of the major discipline of the topic and career prospects in that discipline.
- Give a taste of what engineers and scientists do in the area related to the topic.
- Use examples and hands-on activities to explain ideas and concepts.
- Emphasize the need to understand the fundamental concepts in basic sciences, mathematics and engineering to solve engineering problems.
- Emphasize the need to work in interdisciplinary teams and the need to develop communication skills.

V. Conclusion

Native American community is highly under-represented in the science and engineering workforce. North Dakota has a significant NA population dispersed in five Reservations. Each Reservation has a Tribally Controlled Community College in it. High schools in the Reservations and adjacent areas feed students to the TCCCs. Some students from these community colleges do transfer to four-year institutions such as North Dakota State University. In order to increase the NA students enrolling in science and engineering programs, activities need to be designed to motivate and attract Reservation high school students to science and engineering college education. Sunday academies and summer camps reported in this paper are part of a larger effort undertaken collaboratively by the North Dakota State University and TCCCs under a multi-year project funded by the Office of Naval Research[4]. These activities strengthen the pathways to engineering careers for NA students of North Dakota Reservations. Apart from the direct benefits to students, these activities have created a collaborative and co-operative climate for the NDSU and TCCC faculty and the Reservation high school teachers to work together.

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VI. Acknowledgment

The authors acknowledge that the work reported in this paper was carried out as part of the project "An Adaptive Systemic Initiative of Tribal Collaboration for Increasing Native American Participation in Mathematics, Science, and Engineering" funded by the Office of Naval Research, United States Navy under Grant No: N00014-99-1-0969.

VII. References

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Figure 1. Native American Student Pathways

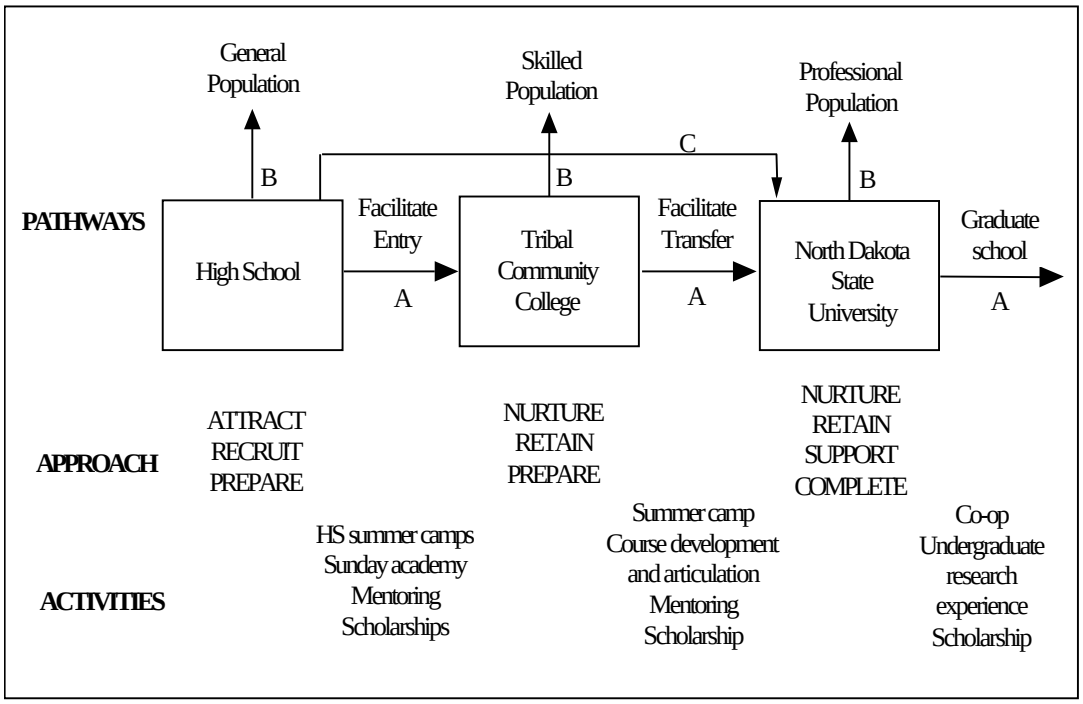

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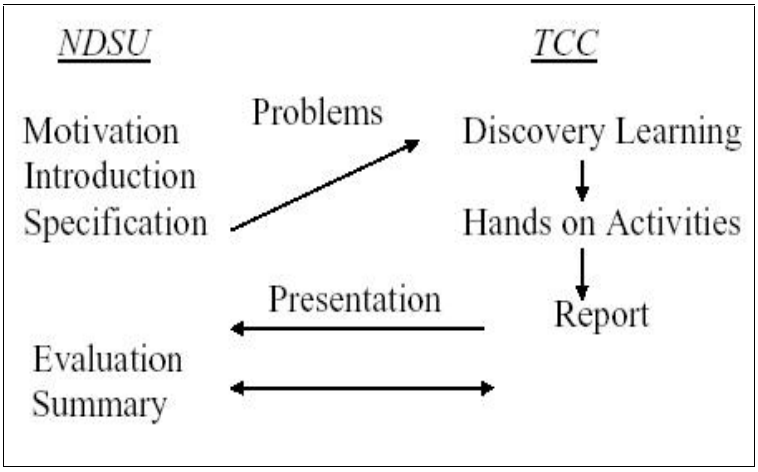
Figure 2. Sunday Academy Session Activity Flow



Biographical Information

CAROL DAVIS
Dr. Carol Davis is Vice President of Turtle Mountain Community College at Belcourt, North Dakota. Dr. Davis is the Principal Investigator of the project reported in this paper. She also is a Co-Principal Investigator of a National Science Foundation Rural Systemic Initiative project, which serves nineteen American Indian tribes in six states.

G. PADMANABHAN
Dr. G. Padmanabhan is Professor and Chair of the Department of Civil Engineering and Construction at NDSU. He has more than twenty years of teaching and his area of expertise is water resources. Dr. Padmanabhan is a Fellow of the American Society of Civil Engineering and a Member of the American Society for Engineering Education.

ROBERT PIERI
Robert Pieri is Professor and Mechanical Engineering Chair at NDSU. Ten years of his teaching career were spent as an instructor/professor at the United States Air Force Academy (USAFA). Dr. Pieri has a ten-year involvement with the American Society for Engineering Education and has served as a co-chair for ASEE's Engineering Educator Division.

WEI LIN
Dr. Wei Lin is an Assistant Professor in the Civil Engineering Department at NDSU. He received his Ph.D. in civil/environmental engineering from State University of New York at Buffalo. Dr. Lin teaches environmental engineering courses at NDSU. He uses real-life applications in his environmental engineering courses.

FLOYD PATTERSON
Floyd Patterson is an Associate Professor of Electrical Engineering at NDSU. He has been a faculty member at NDSU since 1968. Professor Patterson has several years of experience teaching the introductory and motivational material to Electrical Engineering freshmen. In this course he illustrates physical phenomena in graphical and/or mathematical form using MATLAB.

SHARON COBB
Sharon Cobb is the Director of the Group Decision Center at NDSU. She has developed the NDSU Cooperative Education Program, which realizes over 600 placements annually, with a network of nearly 400 active employers. This campus-wide program served as the employer base for the project.

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