A Successful Partnership between Industry and Academia: Curriculum Improvement, Research, and Outreach through Collaboration with Industry

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Abstract

The Public Service Company of New Mexico (PNM) has been working on an Energy Storage Project. This project is the nation’s first solar storage facility fully integrated into a utility’s power grid. This award-winning project demonstrates that a battery system can be used to effectively address the challenge of intermittency. The high-tech battery system smooths out fluctuations in solar power output caused by clouds, and it stores excess energy that can be shifted or dispatched when it is most needed.

Through a partnership with PNM, Northern New Mexico College (NNMC), a Hispanic and Native-American serving institution, has played an active role in the project. In this collaboration, the Department of Engineering and the Math Department have: a) improved the curriculum for two engineering bachelor programs; b) contextualized assignments for developmental math courses; c) provided access to state-of-the-art solar data for undergraduate research; d) developed an outreach component to involve hundreds of local middle school students in solar energy projects.

The case study discussed in this paper describes the collaboration strategies that have shaped NNMC’s involvement in the project. In particular, the paper addresses the funding model; the role of faculty, students, and PNM’s personnel; project marketing; project sustainability; the interplay of these strategies to create a win-win relationship for NNMC, PNM, and the local community.

Examples of curriculum developed and implemented are presented throughout the paper. A summary of statistics and results of the collaboration is also presented.

I) Introduction

In recent years, the literature has addressed the importance of boosting collaboration among industry and academia. This type of collaboration has been identified as an invaluable way to leverage resources. On the one hand, it provides funding to universities that are struggling with decreasing budgets; on the other, it provides industry with academic talent working in relevant research areas in the industry’s field. This is in the same spirit as several recommendations in the report last year of the Committee on Research Universities, et.al.

In 2009, NNMC was approached by PNM, the largest utility company in New Mexico. The purpose was to invite the Department of Engineering to become one of the partners pursuing one of the Department of Energy’s Smart Grid demonstration projects funded by the American Recovery and Reinvestment Act of 2009.
After the grant was awarded, PNM and NNMC signed a service contract specifying the collaboration scope which involved research, data analysis services, and curriculum development.

For a Department of Engineering that has only existed for five years, this contract became the first formal collaboration agreement with industry and, therefore, is meaningful for the future of the engineering programs offered. It has become evident that partnerships between colleges and industry are great resources to produce a better-prepared work force.

This paper presents the different elements of the collaboration between PNM and the Department of Engineering of NNMC. The paper is organized in the following way: first, a general background of the project is presented; second, a general description of NNMC’s participation in curriculum improvement and research projects, including curriculum samples; third, statistics of student and faculty participation; fourth, a general discussion of achievements and sustainability.

II) Background

The Energy Storage Project in which NNMC participated is the nation’s first solar storage facility that is fully integrated into a utility’s power grid. The project features one of the largest combinations of battery storage and photovoltaic energy in the nation. The goal of the project is to develop a way to manage solar energy and other renewable resources so they can be accessed and used when they are most needed.

The project demonstrates that a battery system can be used to effectively address the challenge of intermittancy. It uses high-tech battery systems to both store excess energy and to smooth out fluctuations in solar power output caused by clouds. The excess energy can then be shifted or dispatched when it is most needed, as for example, in the evening when the sun is not shining.

The project is part of a nationwide effort to help the economy, develop reliable renewable energy, and research battery-storage technology. The large, 2158 panel solar array is located on a 4.9 acre site and produces up to 500 kW of electricity. It includes 8 battery-containers of 160 batteries each with a storage capacity of 50 kilowatts per hour delivered over four hours (or 1 megawatt-hour).

The project has involved extensive research and development of smart grid concepts with a number of project partners including two state universities, one national lab, and several private companies.

Specifically, NNMC is located in a rural area. The student body demographics is 73% Hispanic, 11% Native American students and 16% other. At large, it serves a community with a population of 10,495 inhabitants with a medium household income (2005-2009) of $34,186 USD, according to the 2010 US Census Bureau. The Department of Engineering and its programs have existed for five years, and the current
total enrollment for both bachelors and associates is 110 students. The department offers a bachelor in information engineering technology and a bachelor in mechanical engineering with a concentration in solar energy. Due to this fact, it is clear that our involvement enhanced the broader impact of the project. This collaboration has provided some technical resources that are not typically available for an institution of our size and location.

The scope of the general project for NNMC included the following requirements:

- Retrieve and store data from a minimum of 102 data collection points at the battery/photovoltaic (PV) site. The data is sampled at time-intervals that vary from one second to one minute.
- Develop and implement a data model to capture data being generated by the battery/PV site (see site in Figure 1).
- Distribute selected data to partners and other internal and external business partners for analysis.
- Provide secured access to specific systems for selected project partners.
- Provide required security to protect confidential/proprietary data.
- Address any security requirements necessary to protect the Utility computer network, electric distribution, and telecommunication systems.
- Provide specifications and requirements to telecommunication to insure sufficient bandwidth and physical infrastructure to support the data traffic.

The 102 data collection points included: temperature and irradiance in PV array, input and output voltage/currents in the battery charge controllers, photovoltaic controllers, three-phase voltages and currents in inverters, voltages, current and power stabilization batteries, and, in peak, shaving batteries, SCADA meters, etc. Due the number of data points and the one-second sampling period, this project fits in the realm of “big data”.

Figure 1: Photovoltaic Site.
III. Educational Outreach Activities of the Project

III.a) Scope

At the beginning of the project in January, 2011, NNMC’s participation consisted in four tasks: i) baseline data acquisition; ii) data acquisition and optimization research; iii) data retrieval reduction, manipulation, and reporting; iv) reporting on battery and PV performance. However, as the project evolved, there was an increased interest by PNM in fostering the educational outreach goals of the Project. Specifically, NNMC was asked to work on the dissemination of the data to broaden the impact of an already successful project.

The core of participation for the period September 2012-December 2013 included the incorporation of state-of-the-art solar data into the curriculum of diverse programs and student learning activities.

The main strategies that were implemented included:

• Curriculum development to incorporate the solar energy data in current courses and in one new course.

• Learning experience development for the Friday Academy.

• Learning experience development for the Summer Bridge Program.

• Undergraduate research experiences, including a field trip.

• Kiosk, website, and Android application development.

These strategies are explained in what follows.

III.b) Strategies

1) Curriculum Development

Faculty members both from the Department of Engineering and the Math Department decided to improve the curriculum offered by embedding the solar energy data from the project. The massive database was an incredible resource for curriculum enhancement. Table I summarizes the different activities and it also includes the term in which the activity was developed and implemented. A brief description of the deliverables is offered next.

First, the solar energy database was used in the course IT-250, “Introduction to Databases”. In this engineering course, students learn information retrieval by queries. Data was uploaded into a MySQL server, and students then built SQL-queries to extract values by using a time range, or they calculated the average of the power output during a
specified period of time. The solar energy data provided more variables to be used in the lab sessions. A one hundred-page lab manual was developed including eleven lab sessions where students learn how to process and manipulate a huge numerical database.

Table I: Description of curriculum development activities.

<table>
<thead>
<tr>
<th>Course or Event</th>
<th>Term</th>
<th>Deliverables</th>
</tr>
</thead>
<tbody>
<tr>
<td>Introduction to Databases Course</td>
<td>Spring-Summer 2013</td>
<td>• A manual with ten laboratory experiments</td>
</tr>
<tr>
<td>Calculus and Math Practicum</td>
<td>Fall 2012</td>
<td>• Assignments</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Homework</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Final report with statistics of success</td>
</tr>
<tr>
<td>New course: Data Analysis and Statistical Learning Course</td>
<td>Spring 2013</td>
<td>• Homework assignments</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Mid-term project</td>
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<tr>
<td></td>
<td></td>
<td>• Final paper</td>
</tr>
<tr>
<td>Math Foundation of Computer Science Course</td>
<td>Fall 2012</td>
<td>• Online lecture materials related to linear programming optimization</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Power-point slides from lectures</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Four lab experiments with lab manuals</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Publication in &quot;5 de Mayo” conference</td>
</tr>
<tr>
<td>ME Capstone Course I</td>
<td>Spring 2013</td>
<td>• Power Point presentations on ethics on the Capstone project</td>
</tr>
<tr>
<td>Linear Algebra</td>
<td>Spring 2013</td>
<td>• One assignment on least-squares’ method</td>
</tr>
<tr>
<td>Friday Academy</td>
<td>Fall 2012 - Spring 2013</td>
<td>• Assignment for plotting PV and analysis on the need of smoothing/shifting/storage to satisfy the demand peak</td>
</tr>
<tr>
<td>Developmental Math Programs &amp; Summer Bridge</td>
<td>Fall 2012 - Spring 2013</td>
<td>• Lecture materials using PV data for different developmental math classes</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Matlab homework assignments using PV data for different developmental math classes</td>
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<td></td>
<td></td>
<td>• Material presented at the mobile seminars related to data analysis at the PI-seminar series</td>
</tr>
<tr>
<td>Research Experience, “An Android-based Mobile Application”</td>
<td>Fall 2012- Summer 2013</td>
<td>• Mid-Project Report</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Alpha/Beta/Final Version Release</td>
</tr>
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<td></td>
<td></td>
<td>• Presentation in the local &quot;5 de Mayo&quot; conference</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Publication in Google Store for public release</td>
</tr>
<tr>
<td>Research Experience, “Optimizing PV Impact Through Storage”</td>
<td>Spring 2013- Summer 2013</td>
<td>• Presentation in the local &quot;5 de Mayo&quot; conference</td>
</tr>
<tr>
<td>Research Experience, “An Android-based Mobile Sensing System for Cloud Tracking”</td>
<td>Fall 2012- Summer 2013</td>
<td>• Mid-project report</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Alpha/Beta/Final version release</td>
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<td></td>
<td></td>
<td>• Presentation in the local &quot;5 de Mayo&quot; conference</td>
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<tr>
<td></td>
<td></td>
<td>• Final project report</td>
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</tbody>
</table>
The curriculum for Calculus I and Math Practicum was also enhanced. The data is ideal to introduce students in Calculus I and in a Math Practicum (albeit at different levels of difficulty) to graphical interpretations of first and second derivatives, maxima and minima, and numerical approximations of the derivative using finite difference. Simple Matlab/Scilab codes were developed to read the data and to do numerical calculations pertaining to derivatives, integrals, and simple differential equations related to the topic. Numerical integration is not a typical topic in this entry-level Calculus I class. However, using the actual data, this topic was of real interest to the students in the class, the majority of which are engineering students.

Math Foundation of Computer Science is another course that embeds new activities using the solar energy data. A module on linear programming (LP) was developed within the course. Students learn LP through a real problem with the actual solar data and learn to apply algorithms to adjust the different parameters involved in the problem.

![Conventional Power Plant](image1)
![Solar Power Plant](image2)
![Battery Storage](image3)

**Figure 2:** Energy scheduling problem with two energy sources.

Figure 2 illustrates the proposed project for linear programming in the sophomore course, CS-201, "Mathematical Foundations of Computer Science". Students manipulate real data collected from a solar power plant (upper right corner). Data includes the power generated and fed into a battery storage bank (lower right corner) or into the electrical grid (center) used to satisfy customer demands. The problem can be cast as a linear program, where the objective function is:

\[
P = \sum_{i=1}^{24} \left[ P^C_i E^C_i + P^{PV}_i E^{PV}_i + P^B_i E^B_i \right]
\]

where \( P^C_i, P^{PV}_i, \) and \( P^B_i \) are the profit per energy unit for the conventional power plant, solar plant, and battery storage, respectively, during hour \( i \).

Linear Algebra is another course that improved its curriculum content. Students learn to use the data to construct a quadratic function to fit actual data where the coefficients are determined by the method of least squares.
A new upper division engineering elective course, “Data Analysis and Statistical Learning”, was developed and implemented. Students were exposed to the concepts of “big data” science including several raw data analysis techniques. This project was beneficial for the class as it became an excellent data source for learning due to its richness and its relevance to engineering students.

To illustrate how the curriculum was enhanced, some examples are shown next.

**Calculus example:**
The performance of a photovoltaic system depends on the irradiance (kW/m²), the power of electromagnetic radiation (solar radiation) per unit area. On sunny days, it produces energy that resembles a smooth, bell curved. Using the irradiance data, find the insolation H (kJ/m²), by calculating the integral of the irradiance with respect to time:

\[
H = \int_{t_0}^{t_f} I(t) dt
\]

Where \( t_0 = 8:00 \) and \( t_f = 16:00 \) are the time boundaries where we want to compute the insolation. Consider \( dt = 1 \) min.

**Linear Algebra example:**
Using the solar irradiance data, fit the least squares quadratic function.
In the least squares quadratic fit, the following equations need to be solved,

\[
\begin{align*}
y_1 &= ax_1^2 + bx_1 + c \\
&\vdots \\
y_n &= ax_n^2 + bx_n + c
\end{align*}
\]

In matrix form, one has, \( A\vec{w} = \vec{y} \), where,

\[
A = \begin{pmatrix}
x_1^2 & x_1 & 1 \\
\vdots & \vdots & \vdots \\
x_n^2 & x_n & 1
\end{pmatrix}, \quad \vec{w} = \begin{pmatrix} a \\ b \\ c \end{pmatrix}, \quad \vec{y} = \begin{pmatrix} y_1 \\ \vdots \\ y_n \end{pmatrix}
\]

The least squares function \( f(a,b,c) = \sum_{i=1}^{n} (y_i - ax_i^2 - bx_i - c)^2 \) is minimized by solving the matrix system, \( A^T A\vec{w} = A^T \vec{y} \).

Use the solar data available from the PI Server and run a Matlab program using 50 points to perform the least squares fit for both linear and quadratic least squares functions.

2) Learning Experiences Development for Friday Academy

The literature has reported some misconception among middle school students when they are asked about what engineering is. The report shows that the students’ beliefs and
conceptions are not changed even after they are exposed to the established curriculum at their middle school.

As a way to motivate students to learn and pursue a degree in STEM, NNMC has developed a program to address this challenge. The Friday Academy is an institutional program where middle school students from the local public schools come to NNMC’s facilities, two Fridays a month, and learn from college faculty relevant topics in STEM areas: math, engineering, and environmental science.

The sessions are very hands-on, and the students are exposed to state-of-the-art facilities and software. Topics in conceptual math and computer programming in Matlab are always fruitful learning experiences for the students. In this case, our faculty developed learning experiences using the solar energy data to make students aware of the implications of photovoltaic generated energy. In parallel, students learn Matlab & Excel to create plots of data and to understand how data is used. For example, PV peak compared with demand peak is a topic that the students investigate by plotting actual data.

An activity plan was developed for one hour and a half session (these sessions are repeated four times per Friday). Each session brought around 20 students; thus, between 80-100 students were exposed to these concepts every Friday.

Figure 3 shows a simulator built for the Friday Academy sessions. Students use it to learn the correlations of power and temperature. They also see the output power increase after a day of rain. The rain cleans the dust from the solar panels.

Figure 3: Simulator build for the middle school students.
3) Learning Experiences for the Developmental Program and Summer Bridge

Every summer NNMC implements a Summer Bridge program that offers remediation courses and a math accelerator program for freshmen students who are not ready for engineering and science courses due to weaknesses on their math background. Approximately, 60 students participated in the project: 40 at the developmental level and 15-20 at a more advanced but still remedial level. Fifteen students in the advanced level program were exposed to workshops using the solar energy data.

At NNMC, ninety percent of the students have to take at least one developmental math course. Therefore, the developmental classes were targeted with relevant and novel content to help students understand the math applications using real data that is relevant to society and sustainability. Teaching developmental mathematics differs substantially from simply teaching mathematics. Developmental instruction addresses not only the remediation of the subject-specific deficiencies but motivational and learning deficiencies as well. In order to understand mathematics, students need much more than procedural fluency. Contextualization is one way to improve outcomes for academically underprepared college students. This method is grounded in a conceptual framework relating to the transfer of skill and student motivation\(^1\). Contextualization is defined as an instructional approach that creates explicit connections between the teaching of reading, writing, and math. Contextualization of basic skills is used as a way to engage students, deepen content learning, promote transfer of skills, and make what they learn part of themselves. Students are more likely to transfer the skills to subject-area learning when the math instruction is connected to these subject areas rather than taught abstractly.

The actual data was used and embedded in the math curriculum. In doing this, students were instructed to make the connections of the math concepts they learned. This transpired outside the classroom through the insights they gained with regards to PNM services, projects, and data. Matlab and Excel were used as students became familiar with the data, especially in the more advanced remedial courses. Parallel exercises using simplified data were used as introductory material and upper classman within the Department of Engineering talked to the students about “raw” data and its usage.

In particular, for the Basic Algebra courses (Math 100 and Math 103) and Intermediate Algebra (Math 130) a diverse population of students from all types of programs were impacted: biology, environmental science, engineering, business administration, nursing, auto body repair, general studies, accounting, criminal justice, wild land fire science, psychology, humanities, and automotive technology among others.

As the instructors and their student assistants learned to use the solar energy data, mobile project seminars as teaching aids were developed. These mobile seminars are ready to be delivered to any class, math or otherwise, that recognizes a need for such data and its analysis in a teaching context.
Developmental Math students learned three things:

1. The sun’s daily and yearly cycle.
2. How solar panels function and their history.
3. How to graph with Excel.

Some students in the developmental math classes (Math 102 and Math 130) knew a little about each of the above three items. None were well-versed in all of them; this opened up a teaching opportunity. Fitting real-world irradiance data into a graph (a hands-on math project) gives meaning and relevance to the abstract world of math where students, perhaps too often, dwell, and get bored.

a. The class held a discussion of what the sun does in a given summer day, winter day, spring day, and fall day. As a note: only a few students, surprisingly, knew that there were longer and shorter days during the solar year or that the sun was lower and higher above the horizon on different days of the year.

b. After a general consensus was reached about the solar year, a data sheet was passed out and the names of the classical divisions of the solar year were presented, including their etymologies.

c. Students were asked to graph from their own experience the hours of sunlight they thought this area of the state received in a given year, beginning with January and ending in December.

d. Students were asked in the next class session to graph on one graph the difference in length between a solar day in January vs. December (no clouds)—length of day and irradiance. When this was completed by hand successfully, they were asked to add to the same graph what an equinox day would look like.

e. Students were taken on a tour of solar PV sites on campus. There are two. One is a small stand-alone panel that powers an on-campus weather station. The second is a much larger array (six panels) mounted on a tracking system.

f. Students were taken on a separate day to see the operational lab-sized PV solar panel with accompanying equipment (digital multimeter, monitor, power inverter, load unit, charge controller).

g. Students were given a 20-minute lecture on the history of solar PV production that included information on how efficiency has gone up while costs have gone down for solar PV panels.

h. Students were introduced to the use of Excel by graphing random data in order to become familiar with the system.

i. Students were given access to several days of irradiance data, learned how to put it into Excel and how to graph it, how to produce a title for the resulting graph, and how to label the graph’s coordinates. Results were often very handsome parabolas.

j. The resulting parabolas were then subjected to regression requests within Excel, and best-fit functions for quadratics were produced.

k. Finally, the students used Excel to generate the function for the best-fit regression. The result, a quadratic equation, made a positive impression on the students. And they saw how math and the real world were (could be) connected. In addition, they were on their way to perceiving the power of the Excel program.
4) Undergraduate Research Experiences

Several faculty members engaged with junior and senior students as mentors under several research projects. Some of the projects are described below.

Project 1:
To address the increase of demand for electricity, the need for reducing carbon dioxide, and the reduction of available fossil fuel resources, renewable energy sources are being recruited. Specifically, energy generated by photovoltaic (PV) cells is one of the most promising alternatives. In this context, an optimization model for the scheduling problem was studied. The optimization model was formulated as a Linear Program (LP) with a bounded number of variables and constraints. The respective solution was obtained in polynomial time and provided the optimal combination or schedule of energy generated from different sources (conventional, renewable, and battery storage) such that the total demand is satisfied and the profit is maximized. Numerical results demonstrated the effectiveness and the generality of the scheme and led to the drawing of valuable conclusions.

Project 2:
In this project, the characterization of the solar power produced by the site was studied. Variation and periodicity were characterized for the solar energy irradiance for a period of one year (December 2012-November 2013). Results included a profile of the signal power and variation during the different months (frequency components) and spectral energy production.

Project 3:
A system was developed to provide cloud-cover information based on pictures taken by the mobile device’s camera. Machine learning tools were utilized to develop models to classify the pixels as cloud or sky pixels using Naive Bayes and J48 algorithms. After the models were created, no statistical difference was identified that would calculate the cloud cover. However, the models failed to identify cloud pixels when the sun was in the field of view of the device. A paper was written to summarize the project.

Project 4:
During Summer 2013, a smoothing scheme was developed to smooth the data and graphically represent the fields using MATLAB. An algorithm was also developed in MATLAB to compute the theoretical irradiance for any latitude, day, and hour. Comparisons were made between the theoretical irradiance and actual irradiance. Efficiency (from power and irradiance) and temperature correlations were computed using the data.

In Fall 2013, a variety of smoothing schemes were investigated for the solar data. Fast Fourier transform truncation was considered as well as a weighted moving average and digital low pass filters. With regards to digital low pass filters, a code in Fortran was developed to filter a time series using Butterworth and Chebyshev filters. A transfer function was constructed and used to compare the theoretical gain and time delay. The actual gain and time delay was computed by filtering a single frequency sine wave.
Project 5:
In this project, the goal was to find correlations between solar energy irradiance and local weather parameters, the ultimate goal being to construct a prediction model based on weather forecasting for the days that followed. The data type used was irradiance, weather calendar, and hypothetical irradiance for the site. The goal was to find correlations between the irradiance and common weather descriptions such as cloudy, scattered clouds, overcast, rain, winds, dust, and thunderstorms.

Finally, it was important for the project participants, students and faculty, to know more about the actual infrastructure of the PV solar site. In Fall 2013, PNM and NNMC organized a field trip. The visit was fruitful for the attendees who learned more about the project and who might generate new ideas on how to use the data (Figure 4).

5) Kiosk and Android App Development

The project involved the development of an Android-based application for education and dissemination of information about solar energy technology as well as real-time graphing of variables from the project (Figure 5). The application displays real-time power and irradiance that is generated from the solar PV site. The application is a powerful tool to disseminate the project that is available as a free, downloadable app from the Internet through the online market Google Play. PNM and NNMC have benefited from this app in their marketing efforts.

Another undergraduate project was the development of a computer-based kiosk. The kiosk was placed in a public space at the engineering building of NNMC. The touchscreen kiosk displays real time data coming from the project and provides general interest statistics about solar energy (for example, equivalent houses powered by the energy that is collected). The development took place in Fall 2012, and became a useful tool for enhancing public awareness about efforts to bring clean energy to the state. People walking to the building are attracted to the kiosk (Figure 6).
IV) Project Statistics

Table II summarizes some relevant statistics of this project.

<table>
<thead>
<tr>
<th>Financial information</th>
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<tbody>
<tr>
<td>Contract amount for the total project: $327,000.</td>
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<tr>
<td>One research professor entirely supported by the project for fifteen months.</td>
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<tr>
<td>Faculty members who received stipends: nine members at a stipend rate of $33/hr.</td>
</tr>
<tr>
<td>Faculty members who received summer contract extensions: two faculty members.</td>
</tr>
<tr>
<td>Students who received stipends: eleven students at a stipend rate of $20/hr.</td>
</tr>
<tr>
<td>Labor hours worked by faculty and students:  6860 hours.</td>
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</tbody>
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<table>
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<tr>
<th>Undergraduate Curriculum Development</th>
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</thead>
<tbody>
<tr>
<td>Number of classes with curriculum improvement/redesign: 10 courses.</td>
</tr>
<tr>
<td>Undergraduate lecture-hours dedicated to data usage (summer bridge and developmental math are not considered):  65 hours.</td>
</tr>
<tr>
<td>Undergraduate students impacted (summer bridge and developmental math are not considered):  125 total students, 70 female and 55 male.</td>
</tr>
<tr>
<td>Ethnicity and race:  94 Hispanic and 31 Non-Hispanic (2 Native American).</td>
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<tr>
<th>Undergraduate Research</th>
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<tbody>
<tr>
<td>Five students worked in three research projects and one independent study project with six faculty members involved. Three papers have been finalized at this point. One of the papers is currently under review in the Renewable Energy Journal and another was submitted to the IEEE CCNC Annual Conference. Three projects were presented at the “5 de Mayo” creativity and research institutional conference.</td>
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<tr>
<th>Outreach (Middle school-Friday Academy Event)</th>
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<tbody>
<tr>
<td>Total of lecture/lab hours:  7 Fridays, 5 sessions each and 1.5 hours each session.</td>
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<tr>
<td>Total students impacted: 759 in total, 385 male and 374 female.</td>
</tr>
</tbody>
</table>
Others:

- PI Server deployment at NNMC.
- A mobile app for Android was designed and deployed at the Google store.
- A kiosk was designed and implemented.
- A webpage was designed to display all the curriculum material that has been developed, and the material has been posted at PNM SharePoint site as well. The material is public domain and can be used by anyone that consults the NNMC’s website.
- Student/faculty field trip to the Project Site on August 2013.

V) Discussion

V.a) ABET Outcomes

The project helped to attain several student outcomes for the Information Engineering Technology (IET) program through the course CS 201, Math Foundations of Computer Science. In particular, the following outcome of ABET ETAC Program Criterion for Information Technology programs was attained: “The ability to apply discrete mathematics, and probability and statistics, in the support of facilities that process and transfer information.”

By introducing students to Linear Programming and discrete structures in a 200-level course, the IET program can easily cover these concepts in upper-level courses in different contexts (computer networks, databases, web-systems). Additionally, as summarized in Table II, students worked in open-ended research projects, that are aligned with the ABET ETAC outcome: “An understanding of the need for and an ability to engage in self-directed continuing professional development.”

The level of attainment of these outcomes are systematically documented for assessment purposes. These activities are sustainable over time, since the Department of Engineering will continue to have access to the data after the grant has expired.

V.b) Sustainability

This project presents a different focus as compared with many of the industry-academia collaborations. Many of the industry-academia collaborations occurred in the form of co-ops. The reader may notice that the students did not work at any time for PNM and were not exposed to industry interactions. However, through the partnership, the faculty and students got access to state-of-the-art data that became the foundation for several research opportunities and curriculum development. This is very important because the curriculum can be reused for several more years beyond the end date of the service contract. In general, the literature does not include many examples of industry-academy partnerships with an emphasis on curriculum development.
Note that the IT infrastructure that communicates with PNM’s solar energy site will stay on Campus. This will enable continuation of permanent access to the new data that the solar site produces. New research projects will be developed if faculty and students are interested in pursuing them. This type of effort has a long-term effect because the seed funding does not have to stay in order to enable new opportunities for NNMC.

V.c) Broader Impact

According to NSF\textsuperscript{14}, industrial support accounts for the smallest share of academic R&D funding (just under 6%), and support for academia has never been a major component of industry-funded R&D. Since NNMC is a teaching institution that has evolved from a community college to a four-year institution in the last seven years, the funding from this project represented 70% of the research funding available in the Department of Engineering for the academic year 2012-2013. This is remarkable in an era of continuous budget cuts in state appropriations.

Besides the direct impact in terms of improvements to instruction and curriculum, faculty members were pleased to receive extra compensation within the institution, where the last salary increase occurred more than five years ago. This type of project, therefore, incentivizes faculty to search for new and similar opportunities that may translate into new sources of funding.

V.d) Win-win scenario

PNM and NNMC greatly benefited by this collaboration. The outreach element of the project contributed to the success of the project since it gained more recognition from the community that is very aware of the long-term impact on the education of its people. This is beyond the already well-deserved recognition gained from the technical breakthroughs of the project. Some of the projects developed by the students (for example, the Android Smartphone application) have contributed to the dissemination and visibility of the project. As a manner of fact, when the mobile app was released through the Company’s marketing networks, it was advertised in more than 40 national online newspapers providing a greater visibility to NNMC.

The community and, in particular, the highly under-served geographical location of NNMC, has gained access to a state-of-the-art project. Because of the project, hundreds of middle school students and college students obtained a learning opportunity that in most other circumstances would have been very limited.

Overall, this project has shown how PNM benefited from resources supplied by a government grant and by the transfer of research and innovation from academia. Both academic partners obtained resources for research and innovation and have witnessed how the research and innovation has been transferred to industry. This will be an enabler of new relations among government and industrial organizations and academic institutions. The project was nominated as a finalist of the “Platts Global Energy Award 2013”.
V.e) Benefits to the students

College students have benefited from the new curriculum and from the access to the state-of-the-art solar energy data. Although no job opportunities from PNM have been offered to students as yet, it is certain that the tools learned (big data analysis, PI Server, mobile device applications’ development, etc.) have enhanced our students’ resumes.

The project has also contributed to expand the professional network of our students and has increased their visibility because of the publications on PNM’s social networks (such as Facebook).

VI) Acknowledgement

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Bibliography