AC 2012-3778: IMPROVING RECRUITMENT AND RETENTION FOR ENGINEERING DEGREE STUDENTS IN A RURAL HIGHLY UNDER-SERVED COMMUNITY

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Improving Recruitment and Retention for Engineering Degree Students in a Rural Highly Underserved Community

Abstract

This paper presents an ongoing STEP-NSF and Department of Education-CCRAA funded project and recent findings. The project promotes the increase of engineering enrollment from secondary schools through the baccalaureate level among students from Northern New Mexico College (NNMC). NNMC is a minority serving institution located in a rural area with poverty levels below the level established by the Federal Government. Hispanic and Native American students constitute 73% and 11% of the college population, respectively.

The paper presents the social and academic background of the students attending this College as well as some statistics from the main factors that have contributed to low historical retention. It describes later the strategies adopted for the last three years to improve recruitment, retention and graduation rates for engineering degrees: (1) prepare high school students for college-level conceptual analysis, problem solving and the value of experimental replication through a STEM Summer Camp using problem-based learning; (2) supplement college STEM curricula with programs aimed at tutoring college and dual credit students who are at risk with engineering related courses; (3) curriculum and laboratory development to address the high demand of Information Technology majors with industrial credentials through the Cisco® Academy; (4) mandatory advisement for all engineering students; (5) course pre-requisites redefinition to ease early access to the engineering content; and (6) early exposure to the world of engineering for mid school students through the Friday Academy, which include hands-on projects and supplemental tutoring.

This paper presents some preliminary findings and the evolution of the different strategies to improve student retention and recruitment. Some practices are very promising and have started to be replicated in other STEM fields at the institution. Surveys and enrollment/retention data have been used to validate the findings. Student grades have been also used to compare the performance of our students to students worldwide, using the available Cisco® Academy’s statistics.

I. Introduction

In Fall 2006, NNMC changed its mission from a community college to a four-year degree granting institution while keeping the two-year degree programs. In Fall 2008, NNMC developed two Engineering Baccalaureate Programs: Information Technology and Mechanical Engineering (with concentration in Solar Energy). By the same time, the College received two grants to support STEM education: a STEM Talent Expansion Program (STEP) Award from the National Science Foundation and a College Cost Reduction Act (CCRAA) from the Department of Education. With the support of these two grants and through several initiatives of the Department of Engineering Faculty, several strategies were implemented with the following main goals: increase the pipeline of potential engineering students, recruit students for the engineering programs, retain them and ultimately, graduate them.
The strategies described in this paper were selected from best practices well documented in the literature. It was clear that only a comprehensive and synergistic approach would revert the attrition trend that other programs have experienced at the College.

The strategies have been developed at different times with the first activity implemented in Summer 2009. The findings and experiences from each activity have been used as feedback to improve them. After two years of implementation, there are promising results in terms of student success for the engineering programs in comparison to the rest of the college’s programs.

At this stage, the paper is informative and the results are short-term and preliminary because the engineering programs are relatively new and the strategies have been implemented on a very short time scale.

II. Background

The College is located in a rural area of New Mexico. The student body demographics is 73% Hispanic, 11% Native American students and 16% others 9. NNMC served 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, 27.2% of the population and 16.5% of families were below the poverty line 11.

In the Spring 2009, the overall graduation rate reported for the College was only 7%. The current 6-year graduation rate for the main three urban universities in New Mexico is 44% and the three comprehensive regional universities have a 25% in the same indicator 2. The most recent placement indicators at the College show that 93% of the incoming student population is placed in remedial math (Math 100-Math102) and the main student feeder high-school ranking is 3/10 according to Great Schools, Inc. 5.

In Fall 2008, the Computers and Technology Department was transformed into the Department of Engineering. Faculty holding Ph.D. degrees were hired for the first time and some of the students enrolled in the previous associate degrees on Networking, Computer Science, Drafting or General Engineering joined the new bachelor programs.

III. Project Strategies

From the statistics described before, it was clear that the implementation of a successful engineering program would require a multi-angle approach both for increasing the pipeline of students and for assisting students towards graduation.

The strategies adopted by the Department of Engineering were comprehensive and targeted some of the common attrition issues discussed in the literature 2, 4, 10, 12. The strategies were the following:

a) Prepare high school students for college-level conceptual analysis, problem solving and the value of experimental replication through a STEM Summer Camp using project-based learning.

b) Supplement college STEM curricula with programs aimed at tutoring college and dual credit students who are at risk with engineering related courses.
c) Curriculum and laboratory development to address the high demand of Information Technology majors with industrial credentials through the Cisco® Academy.

d) Mandatory advisement for all engineering students.

e) Course pre-requisites redefinition to ease early access to the engineering content.

f) Early exposure to the world of engineering for mid school students through the Friday Academy, which include hands-on projects and supplemental tutoring.

The strategies were not implemented at the same time. Strategies (a), (b) were implemented for the first time on the Summer 2009, (c) and (d) were started in the Fall 2009, and (e) and (f) began in the Spring 2011. All of these strategies are described next:

III.a STEM Summer Camp

From the Summer 2009 to the Summer 2011, three STEM Summer Camps have been organized by the Department of Engineering. The students ranged from 8th grade to 12th grade and they were mixed in the same classroom. The focus of the Camp has been to strengthen college preparedness by offering hands-on experiences in STEM. At the same time a highly personalized tutoring in Math was offered to the students with a 5 to 1 student-instructor ratio. The hands-on experiences were in the form of a four-week project either in Computer Programming, Biology and Environmental Sciences. The camp concluded with a written report and an oral presentation of the project.

With the exception of the first STEM Summer Camp where students just took a traditional “lecture-based” math session, on the rest of the Camps the students were given a pre-test on Math that was used to develop a study plan for each student. The software used to prepare and implement the exams as well as to design the individual study plans was MyMathTest® by Pearson®. The software allowed students to work at their own pace and some extra assignments were given in the form of homework. In average, a student solved around fifty math problems per day. At the end of the four weeks of the summer camp, the students were given a post-test. The emphasis on Math was decided because some analysis on the first Summer Camp showed that senior high schools students who tried to enroll on STEM courses at the college, either as college students or as dual credit students, although were very motivated by the summer experience, they were rejected because of their scores on the Compass exam, which is the placement exam used at the College.

III.b Supplemental Instruction

This activity has been changing to address better the different challenges that have emerged. During Fall 2008, general tutoring was offered through a Student Success Center to anyone who wished to attend it. Math tutors gathered on a common area where student reached them. The tutoring attendance was on a voluntary basis and continued this way until the Fall 2009. By the end of Fall 2009, it was clear that students were not attending the tutoring sessions and it was decided to target the courses that had larger dropout rates. A smaller version of the Student Success Center was created locally at the Engineering Building. Tutoring became mandatory for the targeted classes on Spring 2010. The first class chosen for mandatory tutoring was Computer Programming I. The tutoring was integrated into the course syllabus and students not
performing well in the initial assignments were referred to a tutor and some hours of supplemental instruction were enforced. The success of this strategy was remarkable and other new courses with large dropouts were targeted for mandatory supplemental instruction. The Engineering Physics I, Engineering Physics II classes along with Computer Programming I class were selected on the Fall 2010.

### III.c Curriculum and laboratory development to target jobs on high demand.

One of the main challenges has been student engagement on early stages of the Engineering program. Research has shown that hands-on experiences contribute to improve engagement and retention. An idea that was pursued was to incentivize early engagement by developing curriculum that leads the student toward a potential job even when the student is still taking his/her courseware. The choice was to adapt the Cisco® Academy curriculum to the networking courses of the Information Technology Program. By doing this, students will get the appropriate training to become Cisco Certified Networking Assistant (CCNA) within the first two years of the bachelor program. This strategy is viewed as a “safety net” because entry annual salaries for a CCNA certified professional are around $65K-$80K. Students who cannot finish the bachelor program for any reason can still get a good high pay job by becoming CCNA professionals. Moreover, even if the students were still working in the General Education component of the program, they became engaged with courses in the engineering field.

Laboratories and instruction material were developed and implemented in the Spring 2010. The courses of Computer Networks I, Computer Networks II, Wireless and Mobile Computing and Advanced Networking were entirely renewed and their content was based on the worldwide renowned Cisco Academy. Recruitment events were prepared to market the Cisco Academy College Membership. Salary information for professionals holding these certifications was provided at the recruitment events and it was always a pole of attraction for potential students.

### III.d Mandatory advisement for all engineering students.

At the beginning, there was not a systematic approach for advisement. Basically, an understaff advisement center was in charge of the advisement for all College students. In Fall 2009, the Department of Engineering implemented a model for Mandatory Advisement were the same Engineering Faculty was in charge. Engineering students could not longer register without seen their academic advisor first (typically, students register online). The process was implemented through the usage of a personal identification number (PIN) that was required by the course registration system when students tried to enroll in classes. The students received their PIN from their academic advisor only after an advisement session took place at some point of the semester or during the summer term.

### III.e Course pre-requisites changes to provide early access to the engineering content.

The Wright State University (WSU) developed a model that has been successfully implemented at different universities throughout the nation. The idea of the model is that a new application-based course in Math is the only pre-requisite for basic engineering courses (like Circuit Analysis, Statics, Physics, etc.) instead of the traditional Calculus class. This new course covers the very basics of math that are required to “survive” an engineering class. The Calculus class remains as a required class in the program but in can be taken in parallel with engineering classes
instead of as pre-requisite class. The model provides early access to students that are struggling with the pathway towards Calculus and it keeps them engaged. The model has improved first year retention 8.

The Engineering Faculty adopted the ideas and strategies of the WSU model. The model was implemented both in the Information Technology and in the Mechanical Engineering Program. Although the original model was developed by WSU to address the Calculus bottleneck, the Department of Engineering found it useful to address also the Computer Programming I bottleneck. The curriculum for the Engineering Bachelor Degrees was modified to guarantee early access to the students that were struggling with these two bottleneck courses. The major changes were the following:

- Networking Component. Students were not able to advance on the Information Technology Program because several of the classes have the pre-requisite of Computer Programming. The dropout rate in Computer Programming was very high (more than 60%) with the consequence of students quitting the program because of this class. From the WSU experiment results, it was decided to help the student move forward in other less difficult courses of the program. The sense of accomplishment and academic progress will maybe provide them with the motivation to succeed in Computer Programming. Pre-requisites for Computer Networks I class were removed. This enabled students to move forward in the Networking path without passing first the Computer Programming. Figure (1) illustrates the curriculum changes for the Networking area in the Information Technology Program.

- Mathematics Component. Similarly, for the Mechanical Engineering Program the curriculum was reviewed and the Catalog for 2012-2013 Academic Year will include the “Introduction to Math for Engineering Applications” course. This course will become the new pre-requisite for Engineering Physics I and will provide access to courses such as Statics and Circuit Analysis without the Calculus pre-requisite. The proposed scheme is illustrated in Figure (2).

III.f Friday Academy

Recent local surveys ran by the College recruiters at the local middle school reported than only 36% of the students expressed interest on pursuing College education. Although middle school student opinions may be very preliminary and will change with time, it is a clear red flag for the College. Faculty realized that efforts are needed to increase the student pipeline. To address this problem, Engineering Faculty participated in the development of one strategy named “Friday Academy”. The focus this initiative was to provide middle schools students with hands-on sessions on Science, Math, English and Engineering for one Friday per month. Fifty students from the mid school attended the session during the Fall 2010 and another group of fifty students attended the session during the Spring 2011. The activity has continued on the new academic year 2011-2012. Although no results are reported for this strategy yet, it is an example of the comprehensive long-term efforts that are currently taking place for recruitment purposes. Another consequence of this activity it is its contribution to the College marketing efforts and in some way helps to compensate for the very small budget dedicated to this line.
Figure 1.

Figure 2.
IV. Results

IV.a Findings for the Mandatory Supplemental Instruction activities.

Drop out rates have been selected as the metric used to evaluate the impact of intervening a course with focus mandatory tutoring. A rate decreased is very important since these courses have been considered traditionally as the “filters” in Engineering and have led directly to changes on major or even college dropouts. The Computer Programming I and Engineering Physics II classes were targeted. Tutoring became available from week on. Other factors such as instructor and lab facilities remained unchanged. The results are shown in Tables (1).

<table>
<thead>
<tr>
<th>Computer Prog. I Class</th>
<th>Fail/Drop</th>
<th>Pass</th>
<th>Engineering Physics II Class</th>
<th>Fail/Drop</th>
<th>Pass</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before Mandatory Tutoring</td>
<td>84.21%</td>
<td>15.79%</td>
<td>Before Mandatory Tutoring</td>
<td>64%</td>
<td>36%</td>
</tr>
<tr>
<td>After Mandatory Tutoring</td>
<td>36.84%</td>
<td>63.16%</td>
<td>After Mandatory Tutoring</td>
<td>14%</td>
<td>86%</td>
</tr>
</tbody>
</table>

Table 1.

This experiment has led the Department of Engineering to replicate the effort in other filter courses. At this point, there is also a strong collaboration with the Math Department to work on raising the passing standards in the Math coursework under the assumption that mandatory tutoring will be offered to the students. This will contribute to reinforce the basic problem-solving skills require to succeed in Engineering.

Figure 3. Supplemental Instruction

IV.b Findings from the STEM Summer Camp activities.

To measure the impact of the summer camp activities two different metrics are used. First, a measure of the number of students who have not graduated yet from High School, but have
expressed interest in an Engineering degree after attending the Summer Camp. This data was collected through an exit survey at the end of the camp. Table (2) shows the collected data:

<table>
<thead>
<tr>
<th>Total (Summer Camp Participants who have not graduate from High School yet)</th>
<th>Summer Camp Participants who have not graduate from High School yet and mentioned to be Interested in Engineering</th>
<th>Summer Camp Participants who have not graduate from High School and are not Interested in Engineering</th>
<th>Summer Camp Participants who have not graduate from High School yet and are still Undecided</th>
</tr>
</thead>
<tbody>
<tr>
<td>72 (100%)</td>
<td>8 (11.1%)</td>
<td>52 (72.2%)</td>
<td>12 (16.66%)</td>
</tr>
</tbody>
</table>

Table 2.

Second, the number of students who have already graduated from High School and attended a summer camp and are now currently pursuing a degree in Engineering (not necessarily at our college). Table (3) shows the data obtained from a phone interview.

<table>
<thead>
<tr>
<th>Total (Summer Camp Participants that have graduated from High School)</th>
<th>Summer Camp Participants that have graduated from High School and are Pursuing an Engineering Degree</th>
<th>Summer Camp Participants that have graduated from High School and are Pursuing a Non-Engineering Degree</th>
<th>Summer Camp Participants that have graduated from High School and are not attending College</th>
</tr>
</thead>
<tbody>
<tr>
<td>61 (100%)</td>
<td>25 (41%)</td>
<td>35 (57.4%)</td>
<td>1 (1.6%)</td>
</tr>
</tbody>
</table>

Table 3.

Without further research and analysis, it cannot be assumed that the summer camp is the cause for students to join an engineering degree later. At this point it cannot be determined if these measures indicate causality or only correlation. It is evident, however, that more camp participants have decided for an engineering degree after high school graduation in comparison to the students who have not finished high school yet. This may be a consequence of self-confidence gained from the summer camp. In particular, after the impressive progress that students showed after four weeks of intensive, individualized math instruction. As it was mentioned before, the students were pre-tested and post-tested using MyMathTest® on an exam covering the typical topics that are included in a placement math exam. The pre-test and post-test results for the summer camp 2010 group are shown in Figure (4).
In average, the students improved 146%. Maybe this improvement was another factor that contributed to a better student learning process on the high school math classes taken afterwards and reinforced the student interest to join an engineering degree after graduation.

**IV.c Other Findings: Growth, Retention, Graduation and Academic Standards.**

Both the STEP and CCRAA grants benefit all the STEM programs. These programs include: Bachelor of Biology, Bachelor of Environmental Sciences, Bachelor of Math and the Bachelors of Engineering. However, there has been plenty of freedom in the strategies that every Department/Program has adopted for recruitment/retention during the last two years. In particular, strategies c), d) and e) explained in Section III were only implemented by the Department of Engineering.

Figure (5) presents the growth indicator for the STEM programs at the College. The Bachelor of Mathematics is not considered in the analysis because it is a program which student body has oscillated between two and five declared students per year and, therefore, it is not statistically significant.

![Enrollment Growth](image)

**Figure 5.**

Another interesting indicator that provides insight on the success of the strategies adopted by the Engineering Department is a comparison in retention rates among the different STEM programs. The comparison is important because all these programs received similar funding resources in terms of faculty hires and lab development. It is also relevant because all these programs are typically challenging for students. The last Fall 2010-Fall 2011 retention indicator is shown in Figure (6). Once again the better numbers are for the Engineering Programs.
One of the main outcomes of these efforts is the graduation headcount for the engineering majors. In the Academic Year 2010-2011, the bachelor graduates for the entire college are shown in Table (4). First, notice that Engineering has the second largest number of graduates. This indicator would not be significant if the Engineering headcount were the second largest at the College, but this is not the case.

<table>
<thead>
<tr>
<th>Academic Department</th>
<th>Bachelors Awarded</th>
</tr>
</thead>
<tbody>
<tr>
<td>Business Administration</td>
<td>30</td>
</tr>
<tr>
<td>Engineering</td>
<td>14</td>
</tr>
<tr>
<td>Humanities</td>
<td>3</td>
</tr>
<tr>
<td>Health Sciences</td>
<td>8</td>
</tr>
<tr>
<td>Education</td>
<td>9</td>
</tr>
<tr>
<td>Sciences (Biology, Environmental, Math)</td>
<td>6</td>
</tr>
</tbody>
</table>

Table 4.

A better indicator, therefore, is the ratio between Headcounts per Department vs Graduates per Department. This ratio was calculated for the Academic Year 2010-2011 and it is displayed in Figure (7). The ratio calculated for Engineering was again the second largest among the College degrees (only 2% behind the Business Administration Department).
As it has been mentioned before, the strategies described in this paper were implemented with the goals of recruitment, retention and graduation rate improvement. However, at the heart of all these indicators, still academic excellence and rigor prevailed. For the Engineering Faculty it is clear that the highest potential of the students can only be reached when students are academically challenged. Recruitment, retention and graduation should not be achieved at the cost of some minimum academic standards.

In order to get some benchmarks on the quality of the programs, the Department reviewed some standardized measures that could help to understand the current quality of the programs. The Cisco Academy provided with a solid benchmark. Recalling from Section (III.c), several courses in the Information Technology Program were aligned with Cisco’s Certification curriculum. A comparison on exam grades between our students and worldwide members of the Cisco Academy was chosen as one valid measure. Table (5) presents the grades for the eleven exams of the Networking Fundamentals course. The second and third columns show the results for the two classes that were taught in Spring 2011. Column fourth shows the worldwide average for the same exams. This is only one indicator at this time and more analysis will be required to assess the quality of the program. Future assessment using the Fundamentals of Engineering Exam may be used. However, at this point in time, Cisco Academy information is a good measure to predict that academic quality can be achieved when student support infrastructure is in place and it should not be compromised.
Our students’ chapter exams performances compared with Cisco Network Academy

<table>
<thead>
<tr>
<th>Chapter Exam</th>
<th>Section 1 (≈20 students)</th>
<th>Section 2 (≈20 students)</th>
<th>Cisco Academy (≈415,000 students)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>80.4</td>
<td>76.1</td>
<td>78.3</td>
</tr>
<tr>
<td>3</td>
<td>82.6</td>
<td>86</td>
<td>88.4</td>
</tr>
<tr>
<td>4</td>
<td>82.9</td>
<td>85.4</td>
<td>85.4</td>
</tr>
<tr>
<td>5</td>
<td>91.1</td>
<td>77.8</td>
<td>84.4</td>
</tr>
<tr>
<td>6</td>
<td>93.6</td>
<td>73.4</td>
<td>87.2</td>
</tr>
<tr>
<td>7</td>
<td>97.7</td>
<td>86.4</td>
<td>88.6</td>
</tr>
<tr>
<td>8</td>
<td>94.3</td>
<td>91.4</td>
<td>91.4</td>
</tr>
<tr>
<td>9</td>
<td>94.2</td>
<td>88.4</td>
<td>86.0</td>
</tr>
<tr>
<td>10</td>
<td>97.1</td>
<td>88.2</td>
<td>90.2</td>
</tr>
<tr>
<td>11</td>
<td>95</td>
<td>90</td>
<td>80</td>
</tr>
<tr>
<td>AVG</td>
<td>90.89</td>
<td>84.31</td>
<td>85.99</td>
</tr>
</tbody>
</table>

Table 5.

V. Conclusions

This paper presents some preliminary findings and the evolution of different strategies to improve student retention, recruitment and ultimately graduation in the Engineering Programs. The Engineering Programs are compared to the rest of the College degrees and an initial trend shows that the strategies are producing the promising results. This is a motivation to keep them all in place.

No research has been done at this time to discriminate among the different strategies. It is not clear yet which ones have a stronger influence. This is definitely a line for future work.

Some other College Departments are now discussing on the possible adoption of a similar comprehensive approach. This could improve the general performance of the College in terms of retention and an overall improvement in the academic climate of the College. This will benefit ultimately the Engineering Programs as well.
Finally, it is important to understand that the improvement on retention and graduation rates has not been implemented at the cost of the academic standards of the programs. Initial indicators measured by standardized exams developed by the Cisco Academy show that the Engineering students are performing at a comparable level with the worldwide student body.

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