A Holistic Approach to Improving Undergraduate Performance in Gateway Computer Science Courses Using Discrete Mathematics as a Case Study

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Abstract

The NMSU Computer Science Curriculum has two gateway courses: CS 171 Algorithmic Computation and Math/CS 278 Discrete Math for CS. We define gateway courses as those in which success or failure is a determining factor in whether or not a student becomes a CS major. We targeted these gateway courses, as part of a larger project to improve minority recruitment and retention in Computer Science at NMSU.

Our approach, based in part on input from the students taking the courses, is holistic: we provide support, opportunities and challenges in a variety of academic and non-academic areas, and for a variety of learning styles. In addition to teaching staff, teams for each course include peer mentors and web programmers.

In this paper we will focus on Math/CS 278, its development and implementation as an interdisciplinary course; the successes and failures of our interdisciplinary team-based holistic approach and our future plans.

Introduction: Pathways Overview

A major challenge to the New Mexico State University Computer Science Department is to recruit and retain underrepresented minority students, both undergraduate and graduate, at the same time preparing them to successfully enter the job market after graduation. For a number of years, we have been running summer camps for Native American High School students, teaching math, computer science, and web design.

We have received financial assistance from a National Science Foundation Minority Institution Infrastructure Grant (No EIA-0220590) to extend this program into a full-blown framework for the development of a smooth and seamless pathway for Native American and other students from traditionally under-represented backgrounds to access 4-year and graduate-level degrees.

Within this framework, an immediate challenge is to increase student success rates in two of our gateway courses and improve retention of undergraduate majors. We define gateway courses as those in which success or failure is a determining factor in whether or not a student becomes a CS major. We chose to focus on our introductory course, CS 171 Algorithmic Computation, and

our new course, Math/CS 278 Discrete Math for CS. We started to address this in January 2003 with focus groups to assess student needs and provide supplemental material and tutoring. In August 2003, we expanded this program to include peer mentoring and web based support using a team oriented approach.

Our approach is holistic, in that we approach the student as a person who functions in many interconnected areas including: academic, peers, family, work, cultural, financial. If the student is out of balance in any one area, it will most likely affect the other areas. Through mentoring and academic assistance we are able to address issues in all of these areas and our team framework ensures that the interconnections are recognized. Our peer mentors were trained in cultural sensitivity and have met with directors of various resources available to students on campus, so that they are able to address non-academic issues with students.

Students have a diversity of preferred learning styles. We endeavor to meet as many of these preferences as possible: in addition to traditional classroom and lab, we provide learning in small groups (focus groups), one-on-one (mentors and TA office hours), and by themselves with web-based support. We get as much input as possible from the students to assess our success and provide direction when we need to make adjustments in our strategy.

When completely implemented we will have *pathways* for students starting at high schools and two-year colleges. Students starting on a path will have guidance as they proceed, to ease transitions both socially and academically and spark their interest in computer science. The ultimate goal is to facilitate access to careers in CS to a more diverse student population.

Math/CS 278: A New Course

In the context of minority recruitment and retention, two additional issues were under discussion in our department:

- Improved alignment of our curriculum with the Association of Computing Machinery (ACM) and Computer Society of the Institute for Electrical and Electronic Engineers (IEEE-CS) *Computing Curricula 2001* {1}.
- Some evidence that some of the students who did well in CS 171, our introductory course, were having difficulty passing Math 279 (*Introduction to Finite Mathematics*).

Computer Science majors were required to take Math 279 *Introduction to Finite Mathematics* as a co-requisite with CS 171 and Math 330 *Discrete Mathematics* as a co-requisite with CS 272 *Introduction to Data Structures*. With the goals of increasing the breadth of computer science courses that our majors take and better aligning our curriculum with the ACM-IEEE-CS *Computing Curricula 2001* {1}, we decided to consolidate our architecture and mathematics requirements. This resulted in the elimination of the requirement for EE/CS 363 *Computer Architecture 1* and working with the Mathematical Sciences Department to create Math/CS 278 *Discrete Math for CS* (offered as Math 301 *Special Topics: Discrete Structures* in Spring 2003 and Fall 2003). Math/CS 278 combines the course material from Math 279 and Math 330, with emphasis on mathematics needed by computer scientists, computer science applications, and preparing students to take CS 372 *Data Structures and Algorithms*.

When modification of the Math 279-330 sequence was under discussion, Dr. Steiner {2}did a study of student outcomes in Math 279 from Spring 2000 to Fall 2001, the results are shown in Table 1, and found that 49 percent of students who did not successfully complete the course (this includes students who took the course multiple times). This study pointed to the need for careful consideration of how to modify the courses, where Math/CS 278 should fit within the CS curriculum, and how to provide the best learning environment to ensure greater student success. Math/CS 278 was taught for the first time in Spring 2003 by Mathematics and again in Fall to 2003 by CS under the title of Math 301. The course will continue to be taught alternately by Mathematics and CS faculty. The Pathways program has provided support for faculty from both departments for the last year, which we will discuss in detail below.

Grade	Number	Percent
A	38	15
B	30	12
C	64	25
D	26	10
F	43	17
W	57	22
I	2	1
Total	260	100

Table 1. Math 279 Grades Sp2000-F 2001

In summary, Math/CS 278 was created as an interdisciplinary course that maintains mathematical rigor, introduces students to common data structures used in computer science from a mathematical perspective and provides the necessary mathematical foundation to study theoretical computer science.

Spring 2003

In Spring 2003, Math/CS 278 was taught for the first time as Math 301 and CS started the Pathways program. To understand how to best provide support for students we decided to try a novel approach and ask the students themselves. To this end we initiated "focus groups" for CS 171 and Math 301. The goals of the focus groups were three-fold:

1. To find out from the students what they thought about the level and presentation of the material, what type of web-based supplemental material and tutorial they would find helpful, and what type of support they need to succeed in the courses.

2. To provide supplemental material and instruction to either help the students succeed in the course, or to challenge the students who found the course too easy.

3. To identify students who would be candidates for a fast-track through the major, who might be candidates for undergraduate research projects, who might be able to serve as peer-mentors or tutors, or who might benefit from focused mentoring.

We invited 10 students from each course to participate in the focus groups. After the first few meetings we opened the groups up to all students to increase participation. There were two focus groups for each course. Each group met weekly for an hour (or more), with two graduate assistants. We also met regularly with the professor to coordinate our work with the students. A typical focus group meeting consisted of chatting with the students about how they are and how

the course was going, offering them the opportunity to discuss any concerns they had and ask questions about the course material, this would be followed by a worksheet to help students review, expand and refine their knowledge of the course material. Worksheets were developed with advice from the professor about the appropriate level and about what supplemental material he believed would be helpful. Worksheets that were prepared as supplemental material for the students were posted to the web.

Table 2 provides a breakdown of focus group attendance by final grades received and Table 3 shows focus group attendance by ethnicity. In both tables the numbers in parentheses indicate female students.
The three students, who regularly attended the focus groups and received C grades in Math 301, came into the focus groups struggling, but by the end of the semester were finally mastering the course material. It seems unlikely that they would have passed the course without the supplemental material, tutoring, instruction, and mentoring which was provided in the focus group.

	Focus Groups attended			Total
Grades	0	1-2	>2	
A+	0	0	2(1 F)	2 (1 F)
B	3	0	0	3
C	2 (1 F)	1	3(1 F)	6 (2 F)
D	3	1	0	4
F	7 (1 F)	2	1	10 (1 F)
W	5 (1 F)	0	0	5 (1 F)
Total	20(3 F)	4	6(2 F)	30(5 F)

Table 2. Math 301 Grades, Spring 2003

	Focus Groups attended			Total
Ethnicity	0	1-2	>2	
African-Am.	0	2	0	2
Hispanic.	7	0	1	8
Native-Am.	3 (1 F)	1	0	4 (1 F)
White	10(2 F)	1	5(2 F)	16 (4 F)
Foreign	0	0	0	0
Total	20(5 F)	4	6	30 (5 F)

Table 3. Math 301 Ethnicity, Spring 2003

Although our numbers are too small at this point to make any general conclusions, our results for Spring 2003 showed that students who participated the focus groups more than twice were 89% more likely to pass the course. We also conducted exit interviews with 4 students who did not attend the focus groups more than twice. We concluded from talking to students in the focus groups and the exit interviews that it is critical for students to keep pace with the course material, to get timely feedback on their understanding of the material, and to have opportunities for guided work with others outside of class. Our greatest disappointment of the semester was not being able to get more student participation in the focus groups.

Fall 2003

For Fall 2003, we took the lessons we had learned in the Spring and designed our team-based approach. We decided to focus on three main areas: focus groups, peer mentoring, and web based support. We hired four undergraduate students at 10 hours a week each, two web programmers and two peer mentors. In addition to the regular graduate student TAs for the two target courses, we had three additional graduate students at 10 hours a week each, a coordinator,

a focus group leader and a senior web programmer. Working with the professors teaching the courses we formed a team for each course.

At the beginning of the semester we administered a pre-test to assess the student's mathematical knowledge and questionnaires about their computer science and mathematics backgrounds, their interest in focus groups and mentoring, and their availability to attend meeting outside of class.

Focus groups

The focus groups were run by the TA, with support from our Focus Group Coordinator. There were two one hour sessions each week (except holidays). After the first month we felt that attendance was not where we would have liked, so the team decided to start offering extra credit problems at the focus groups, which could only be turned in at another focus group meeting. Over the semester, attendance at the 27 focus group meetings averaged 4.8 students. Table 4 provides a breakdown of focus group attendance by final grades received and Table 5 shows focus group attendance by ethnicity. In both tables the numbers in parentheses indicate female students.

We had initially hoped to provide supplemental material and focused group work in the focus groups, however it became clear that was not what the students wanted. As they evolved, a typical session would provide the students with an opportunity to ask questions about lectures, homework and exams. If students did not have questions then the TA would ask them questions about the material (all team members were generously provided notes from class by one of the students, which were reviewed for topics which might need clarification). Since the TA did all of the grading, she was aware of areas where students were having difficulties and could tailor her preparation accordingly.

	Focus Groups attended			Total
Grades	0	1-2	>2	
A	0	1	7 (1 F)	8 (1 F)
B	0	2	5 (2 F)	7 (2 F)
C	1	1	2	4
D	0	0	1 (1 F)	1
F	2 (1 F)	1	0	3
W	1	0	0	1
Total	4 (1 F)	5	15 (4 F)	24(5 F)

Table 4. Math 301 Grades, Fall 2003

	Focus Groups attended			Total
Ethnicity	0	1-2	>2	
African-Am.	0	1	1(1 F)	2(1 F)
Hispanic.	1	2	7(1 F)	11(1 F)
Native-Am.	1(1 F)	0	2(1 F)	3 (2 F)
White	2	1	2	5
Foreign	0	1	2(1 F)	3(1 F)
Total	4(1 F)	5	15(4 F)	24 (5 F)

Table 5. Math 301 Ethnicity, Fall 2003

Mentoring

The peer mentor was trained with the help of Student Support Services and in our own internal training based on conversations with minority programs and various campus resources, in areas of cultural sensitivity, confidentiality, and appropriate campus resources.

The mentor contacted all of students who indicated an interest in mentoring, by phone or email or both. Unfortunately, with the exception on one student, none of the students were interested in following up. In response, we shifted the peer mentor duties to have additional office hours providing tutoring for students and greater visibility for the program and to write questions for our practice area on the web.

We found that while there was some overlap between students who saw the mentor and those who attended focus groups, two students in particular, who were repeating the course, visited the mentor, but did not go to focus groups. This may be due to time conflicts, to preferred learning environments (one-on-one vs. small groups), or to feeling more comfortable with another undergraduate.

Web Resources

Our web programmers, working with the TA, Coordinator, and peer mentor, provided a comprehensive web site for the course including: class calendar, class news, focus group news, syllabus, contacts and office hours, homework assignments and solutions, worksheets and a practice area. The practice area provided multiple choice questions on a variety of course topics, offering students the opportunity to test their knowledge in an interactive environment at their convenience. In order to encourage use of the practice area we let the students know that at least one question on the final would come from the practice area.

Conclusions and Future Work

Based on our outcomes this semester, we believe that our team-based holistic approach shows considerable promise to help is meet our goals of recruitment and retention of underrepresented minority students in computer science. Tables 1, 2 and 4 show that the percent of students who received a grade of C or better was 79% for Fall 2003, compared to 37% for Spring 2003 and 52% for Dr. Steiner's study. Some of the key factors in the success of our Math 301 Pathways team this semester were:

- Timely and consistent communication between team members
- Weekly assignments with quick grading turnaround and solutions on the web
- Variety of options offered to students wanting to enhance their understanding of the course material
- Incentives to get students to the focus groups
- Comprehensive and centralized information on the web

Now that we have a working model we will be extending our holistic team-based approach to other courses in our department. We will make focus groups an integral part of the academic fabric of our department and create a cultural climate that encourages student use of these resources. In order to do extend the focus groups without a great additional expenditure of resources we will be investigating ways to better utilize and train our Teaching Assistants to work in the focus group environment. Since the peer mentoring was less successful than we had hoped, we will be starting a mandatory mentoring for all CS 171 students with faculty mentors, backed up by a peer mentor. We also plan to implement the next level of our web-based support by providing tools to help students learn how to do proofs.

References

1. Association of Computing Machinery (ACM) and Computer Society of the Institute for Electrical and Electronic Engineers (IEEE-CS) *Computing Curricula 2001* http://www.computer.org/education/cc2001/

2. Esther Steiner. Summary Sheet: Math 279 Grades at NMSU, Spring 2000 through Fall 2001. Personal communication November 2003.