Broadening Participation in Computing Through Curricular Changes

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Abstract – Mississippi State University (MSU), like many other institutions across the country, has seen a significant decline in the percentage of women and underrepresented minorities in computing fields since the early 2000's. In the 2008-09 year a significant effort was made to redesign the introductory programming sequence in the Computer Science and Engineering Department. This introductory programming sequence is taken by students in computer science, software engineering, computer engineering and electrical engineering. In addition, an introductory, overview of the discipline course was added for computer science and software engineering majors. The redesign of these courses paid particular attention to factors that are known to impact underrepresented groups in computing. In addition, we have expanded our extra-curricular activities for women in the last two years. These activities address the isolation felt by many of these students who are distributed across different classes in the curriculum. This paper will address the impact that these changes have had on the gender and racial diversity of the student body in computing majors at MSU building on the results previously reported.

Keywords: Retention, computing

BACKGROUND AND PREVIOUS WORK

Last year, [Reese, 6] reported on the changes that were made in the computing curricula at Mississippi State. To set the context for this paper, a brief summary is included. Based on literature on retention in the first programming class [Agarwal, 1; Yadin, 7], the language in our introductory and intermediate classes was changed to Python. In the Intermediate Programming class C++ and Python are used side-by-side. In addition, an introduction to the major course was added in the first semester for computer science and software engineering students. This introductory programming sequence is taken by four majors (computer science, software engineering, computer engineering, and electrical engineering). The changes reported in [Reese, 6] were instigated because of an observed high failure rate in these classes. Not surprisingly, when students failed these classes, they also tended to move out of these majors. Previously pair programming had been added to these classes [Carter, 4]. This had some positive impact on the retention but the failure rates in these classes were still too high and this lead to the loss of many students in the first two years of the curriculum. This curriculum change was put into place in fall 2010 and data has been collected since the change on the student success in these classes and retention within the major to assess the impact of these changes, particularly the impact for women and underrepresented minorities.

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Further Curricular Changes Since Last Year

It was reported in [Reese, 6] that the transition from Python to C++ in the second programming course was causing some issues for students in the Intermediate Programming course. One of the reasons this language change was made in the second course was for electrical engineering students who were not required to take the follow-on Data Structures course. After working with the Electrical and Computer Engineering colleagues who were also having concerns about the programming expertise of the electrical engineering majors, the Data Structures course was added to the electrical engineering major requirements. This will lead to modifications to the introductory sequence beginning in the spring 2014 semester to retain Python throughout the Intermediate Programming course and move to C++ in the Data Structures course

EFFORTS TO RETAIN WOMEN AND UNDERREPRESENTED MINORITY STUDENTS

Efforts to Retain Women

For several years activities have been underway to help increase the number of women in the department. Part of the problem that was observed with retention in the early years is that the few women who are in the department are spread out among the different sections of the introductory classes and therefore may not see many other women in their classes. Programs have been put in place to help the female students get to know each other across the different classes to help them see that they are not as isolated as they may believe. Feedback from the female students on these efforts has been positive and more cohesion and better retention in this group has been observed. Some of the efforts that we have instituted are described below.

These programs have specifically targeted recruitment and/or retention of female students in the computing majors.

- National Committee on Women in Information Technology (NCWIT) Aspirations – In 2012-13 MSU became the state of Mississippi affiliate for the NCWIT Aspirations program. Four high-school students and one high school teacher were recognized in March 2013 for their accomplishments in computing. Two of these students are now enrolled at MSU (one in computer science and one in industrial engineering. Sixteen students have applied for this program this year awards. One part of this award is a scholarship for these students if they attend MSU in a computing major. More information on this program can be found at http://www.ncwit.org/programs-campaigns/aspirations-computing.

- Sit With Me Campaign – The Sit With Me program was created by members of NCWIT. The objective is to "validate and recognize the important role women play in creating future technology." Professional women are encouraged to sit with other women and share their career story. MSU has sponsored a Sit With Me event for the past two years. In an informal luncheon setting for undergraduate and graduate women in computing majors, women have shared their stories from career and student perspectives. In 2012, guests included professional women from FedEx Services, computer science faculty, and a local insurance company. In 2013, students had the opportunity to interact with an IBM professional and MSU computer science alumni. More information on this program can be found at http://sitwithme.org/.

- Diversity of speakers in the introductory class – New students in CSE are required to take Introduction to CSE, a two hour seminar formatted course offered in fall semesters. One of the goals of the class is to introduce students to opportunities within the major and potential career paths. In addition to bringing CSE faculty into the classroom to discuss their areas of research, computing professionals are invited to share their personal career stories along with employment opportunities with their respective employers. Careful consideration is given to ensuring a diverse set of outside speakers that reflects the diversity of the student body. It is important for students to see people with similar ethnicity and gender who have built successful careers in the computing field. This diversity also extends to the types of jobs held, emphasizing that not all computing jobs are computer programming intensive.

- Social events to make connections – The department has hosted several social events to help build community with the female students. Luncheons in the department, outings to the bowling alley, and dinner at the department head's home are examples of these events. The department head and undergraduate coordinator (both females) have participated in these events. This has helped to build relationships with

these students and made them more comfortable seeking advice and help when academic issues have come up.

- Pair Programming – Pair programming has been used in our introductory programming labs for approximately 8 years [Carver, 4]. This has been shown to help improve the retention of women and underrepresented students in computing.

- Grace Hopper – For the last 4-5 years the department has worked to send several students to the Grace Hopper conference each year. Early on the department was limited by funding and 1-2 students were all that could be supported. In the last two years generous support from one of our advisory board members (Bomgar) has allowed an increase to 4 students for this even. This helps augment the students who apply for and receive scholarships from the Anita Borg Institute to attend as well. This year seven total MSU students attended the conference.

Efforts to Retain Underrepresented Minority Students

Most of the efforts to retain underrepresented minority students take place at the Bagley College of Engineering level. At the college level funding is in place for a summer bridge program for incoming minority students. This program operates in the second half of the summer session and brings in students who will be starting as freshmen in August. This month-long program provides an opportunity for these students to hone their math and chemistry skills, build relationships with the other participants and upper-division mentors that participate in the program and to get to know the college's diversity coordinator. In the last two summers this program has added a hands-on programming skills component. All students in the summer bridge program (regardless of intended engineering major) participate in this part of the program. Students gain some basic skills with Python programming, algorithm development and usage of their own laptop computer as a computational tool. Currently, there are not enough of these students who have participated in this program to adequately assess the impact on their success in the programming class and/or retention in the major at this time.

IMPACT ON RETENTION OF UNDERREPRESENTED GROUPS

The impacts of the previously implemented curricular changes and the efforts outside the classroom are evaluated using two different assessments: the overall impact of the change on success of students in the introductory programming and the retention of students in the major. The ultimate goal is not simply to get more students through the introductory programming class but to retain these students to graduation in one of the four majors: computer science, software engineering, electrical engineering or computer engineering. With the many changes that have been implemented, it is difficult to determine whether any changes in the retention and graduation rates are due to the particular curricular changes, the support for underrepresented groups, or some combination of these efforts.

Impact on Success/Failure in the Introductory Programming Course

Success in the introductory programming course is considered to be a grade of C or better since this is the requirement to move on to the next course in the sequence. Failure includes students who did not make a C or better or who withdrew from the course, earning a grade of W. This does not include students who leave the course in the first week of the semester when all students are able to freely make schedule changes. As reported in [Reese, 6], the overall impact of this change was a 50% reduction in the failure rate as shown in Table 1.

Table 1. Impact of Curricular Change on Failure Rates in Intro Class

Semester	A	B	C	D	F	W	Total En	Failed	%Failed	Average %Fail
F2008	19	34	27	23	47	7	157	77	49%	
F2009	23	40	41	24	34	14	176	72	41%	44.7%
F2010	49	58	43	7	6	13	176	26	15%	
F2011	43	56	53	12	30	22	216	64	30%	
F2012	101	52	22	9	14	8	206	31	15%	20.2%

Note that in all of these tables, the first two rows (shaded) indicate the performance prior to the changes discussed and the remaining rows indicate performance after the changes. Table 2 shows the impact of this change on the failure rates for female students and table 3 shows this same data for underrepresented minority students. Note that the female students had a lower failure rate before and after the change in curriculum (although the gap had narrowed). For the underrepresented minority students the change had a dramatic impact on their success in the class, nearly doubling the rate of success. However, minority students still have a failure rate that is 50% higher than the average and twice the rate for majority students.

Table 2. Impact of Curricular Change on Failure Rates for Female Students

Semester	A	B	C	D	F	W	Total En	Failed	%Failed	Average %Fail
F2008	3	4	8	2	9		26	11	42%	
F2009	3	10	8	1	2	2	26	5	19%	30.8%
F2010	2	5	5	1	1	1	15	3	20%	
F2011	5	8	6	0	4	2	25	6	24%	
F2012	12	8	1	2	1	0	24	3	13%	18.8%

Table 3. Impact of Curricular Change on Failure Rates for Underrepresented Minority Students

Semester	A	B	C	D	F	W	Total En	Failed	%Failed	Average %Fail
F2008	1	6	9	8	32	3	59	43	73%	
F2009	2	4	13	10	16	4	49	30	61%	67.6%
F2010	2	24	21	2	3	5	57	10	18%	
F2011	4	11	17	9	19	8	68	36	53%	
F2012	20	17	10	2	5	3	57	10	18%	30.8%

Impact on Retention Within the Majors

The second area of retention that was examined is the retention within the major for students in one of the four majors that are concerned with computing (CS/SE/CPE/EE). Table 4 shows the retention within these four majors for students who took the Introductory Programming class in the fall of the year indicated. Although there was an increase in retention after the first year, this seems to fall off some by the third year. This retention will continue to be monitred as more of these students move through the pipeline.

Table 4. Impact of Curricular Change on Retention in the Major Overall

	Majors in Intro. Programming	Retained to second year	One Year Retention Rate	Retained to third year	Two Year Retention Rate	Retained to fourth year	Three year Retention
Fall 2008	108	70	64.81%	59	54.63%	54	50.00%
Fall 2009	121	74	61.16%	61	50.41%	56	46.28%
Fall 2010	139	102	73.38%	85	61.15%	67	48.20%
Fall 2011	145	108	74.48%	85	58.62%		
Fall 2012	138	96	69.57%				

The standard ASEE data that is used to report retention does not consider the year that the students took the first course in the programming sequence but is measured based on the fall semester of the students' first enrollment. The department has been gathering this information for a number of years as part of its efforts to get baseline retention data and attempt to determine the impact of various measures. Tables 5, 6, and 7 report this retention data for CS majors only for the major overall and then for women and African-American (by far the largest underrepresented minority group) students. One issue that makes it difficult to monitor this group is that the numbers of women and African-American students is so low that it is difficult to get any meaningful trends in this data due to the small

sample sizes. Nevertheless, tables 6 and 7 do indicate the same positive impacts beginning with the fall 2010 class. Since these entering students all took the freshman intro class even if they were not yet able to take the introductory programming class because of weak math backgrounds, some of this improvement may be due to the addition of this class. It is encouraging that the number of women has increased at a rate faster than our overall growth in enrollment. This is consistent with national trends as reported by the Taulbee [Zweben, 8] survey and other data sources. (Note that additional data in these three tables should be available before the final presentation that will include another year of retention for each of these groups. This data is not yet available from the Office of Institutional Research.)

Table 5. Retention in the Major Overall for Computer Science

All Students			Continuation Rates			Cumulative Grad and Cont Rates				
Cohort Year	Total Head Count	Avg. ACT	Cont'd to 2nd Year	Cont'd to 3rd Year	Cont'd to 4th Year	Grad. within 4 years	Cont'd to 5th Year	Grad. within 5 years	Cont'd to 6th Year	Grad. within 6 years
2003	25	27.8	80.0%	48.0%	40.0%	4.0%	36.0%	24.0%	16.0%	40.0%
2004	25	27.6	44.0%	28.0%	24.0%	8.0%	16.0%	16.0%	8.0%	20.0%
2005	17	27.5	82.4%	52.9%	47.1%	11.8%	35.3%	41.2%	5.9%	47.1%
2006	22	27.8	68.2%	54.5%	40.9%	18.2%	4.5%	22.7%	0.0%	22.7%
2007	21	28.3	76.2%	66.7%	47.6%	9.5%	38.1%	42.9%	4.8%	47.6%
2008	17	27.2	76.5%	47.1%	41.2%	17.6%	23.5%	41.2%		
2009	28	27.1	64.3%	42.9%	39.3%	21.4%				
2010	38	26.9	78.9%	63.2%						
2011	38	26.2	78.9%							
2012	30	27.9								
2013	34									

Table 6. Retention in the Major For Women in Computer Science

Female Headcount			Continuation Rates			Cumulative Grad and Cont Rates				
Cohort Year	Female Head Count	Avg. ACT	Cont'd to 2nd Year	Cont'd to 3rd Year	Cont'd to 4th Year	Grad. within 4 years	Cont'd to 5th Year	Grad. within 5 years	Cont'd to 6th Year	Grad. within 6 years
2003	4	25.3	50.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
2004	4	23.3	75.0%	25.0%	25.0%	0.0%	25.0%	25.0%	0.0%	25.0%
2005	3	27.3	66.7%	33.3%	33.3%	33.3%	0.0%	33.3%	0.0%	33.3%
2006	2	18.5	50.0%	50.0%	50.0%	50.0%	0.0%	50.0%	0.0%	50.0%
2007	3	25.0	100.0%	33.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
2008	2	22.0	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%		
2009	3	27.0	66.7%	33.3%	33.3%	0.0%				
2010	5	25.4	80.0%	80.0%						
2011	4	26.0	75.0%							
2012	5	25.4								
2013	8									

Table 7. Retention in the Major For African-American Students in Computer Science.

African-American Headcount			Continuation Rates			Cumulative Grad and Cont Rates				
Cohort Year	AA Head Count	Avg. ACT	Cont'd to 2nd Year	Cont'd to 3rd Year	Cont'd to 4th Year	Grad. within 4 years	Cont'd to 5th Year	Grad. within 5 years	Cont'd to 6th Year	Grad. within 6 years
2003	4	22.5	50.0%	25.0%	25.0%	0.0%	25.0%	25.0%	0.0%	25.0%
2004	2	19.0	50.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
2005	4	24.0	75.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
2006	5	22.8	80.0%	60.0%	40.0%	20.0%	20.0%	40.0%	0.0%	40.0%
2007	3	23.0	66.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
2008	4	21.8	50.0%	50.0%	25.0%	25.0%	0.0%	25.0%		
2009	3	21.7	33.3%	0.0%	0.0%	0.0%				
2010	7	24.0	85.7%	71.4%						
2011	8	22.0	62.5%							
2012	4	20.3								
2013	6									

FUTURE WORK

The success rates in the introductory programming sequence and the retention within the major will continue to be assessed to monitor the impact of the modifications are currently being made in the sequence. In addition, the success of students in the microprocessor class and upper-division classes will be monitored to insure that these students are adequately prepared to be successful in upper-division classes. Recruitment of more underrepresented students into the program should also help create a critical mass and build a sense of community among the students in these groups.

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