Program Review - Overall Report

2024 - 2027

Instructional: ComputerInformation Systems & Computer Science

2024 - 2027

Overall Trends

What overall trends do you see in success, retention, program of study, educational planning, and awards over the past 3 or more years?

Overall, students in Computer Information Systems (CIS) courses) have a success rate which stayed virtually flat with an average of 65.7% over the last three full academic years. This is slightly lower than prepandemic rates which averages 69%.

When disaggregated for ethnicity, it's clear that African American student success rates are well below the average. Hispanic student success rates are slightly below average. With the exception of White students, other student success rates dipped during the 2021 – 2022 academic year but are now trending up.
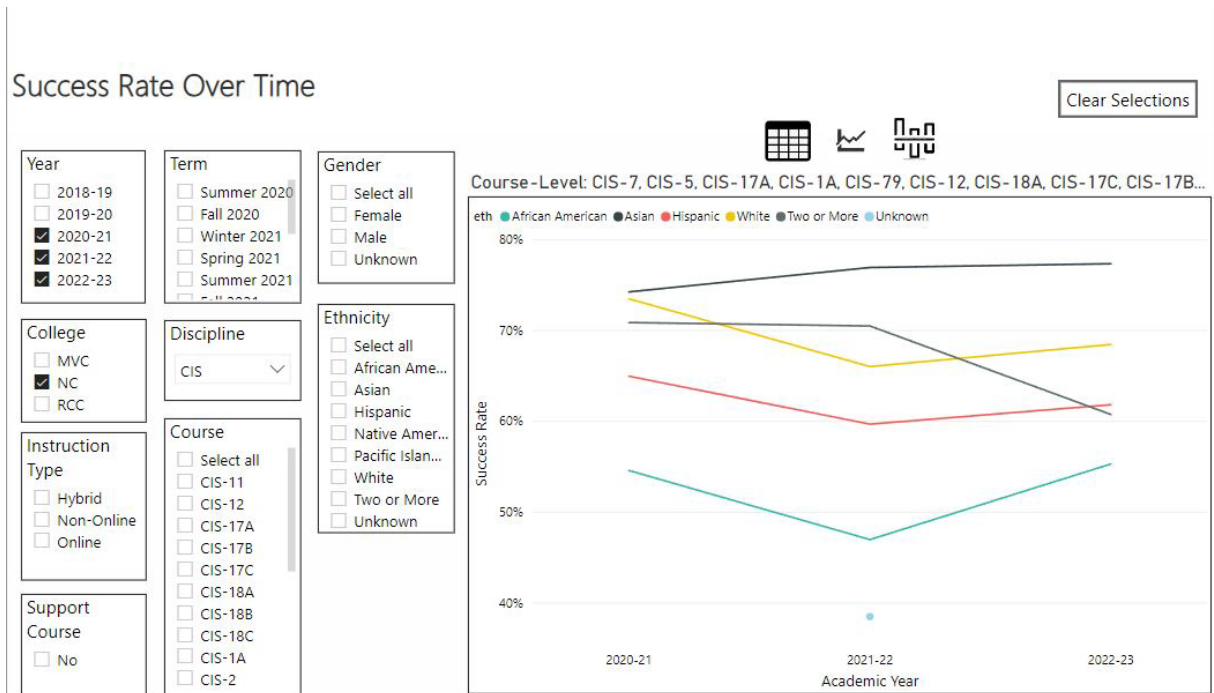
Retention rates have rebounded for the White, Hispanic and African American subgroups.

Data Review

Retention Rate Over Time
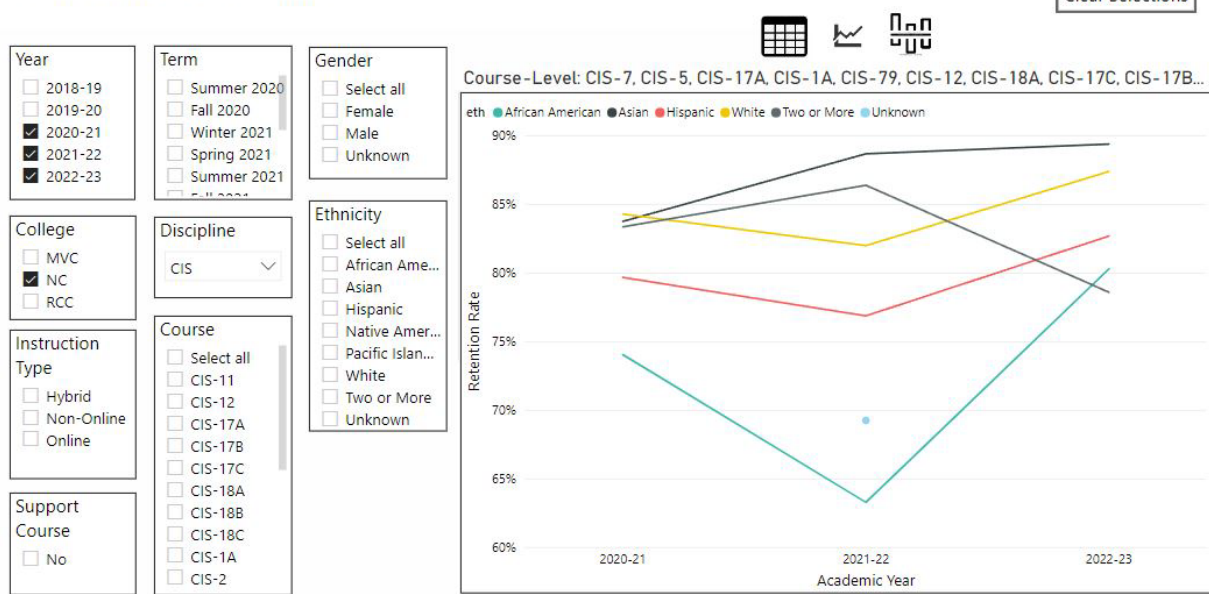
In terms of student subgroups, African American Females and Hispanic Males are showing gaps in success that are concerning. Hispanic Males are also showing gaps in retention that are concerning.

Success Rates by Discipline & Course Disaggregated by Race/Ethnicity

Discipline-Level: CIS

Gender	Enrolled	Success	Success Rate	DI	Close Gap
Female	**1,311**	**862**	**65.8%**	**0**	**0**
African American	69	36	52.2%	1	10
Asian	206	166	80.6%	0	0
Hispanic	730	443	60.7%	1	45
Native American	Masked Data			0	
Pacific Islander	Masked Data			0	
White	243	180	74.1%	0	0
Two or More	48	31	64.6%	0	1
Unknown	Masked Data			0	
Male	**2,848**	**1,871**	**65.7%**	**0**	**5**
African American	132	71	53.8%	1	17
Asian	556	413	74.3%	0	0
Hispanic	1,453	915	63.0%	1	62
Native American	Masked Data			0	
Pacific Islander	10	3	30.0%	0	4
White	583	394	67.6%	0	0
Two or More	98	66	67.3%	0	0
Unknown	14	8	57.1%	0	2
Unknown	**30**	**21**	**70.0%**	**0**	**0**
African American	Masked Data			0	
Total	**4,189**	**2,754**	**65.7%**	**0**	**0**

Course-Level: CIS-5

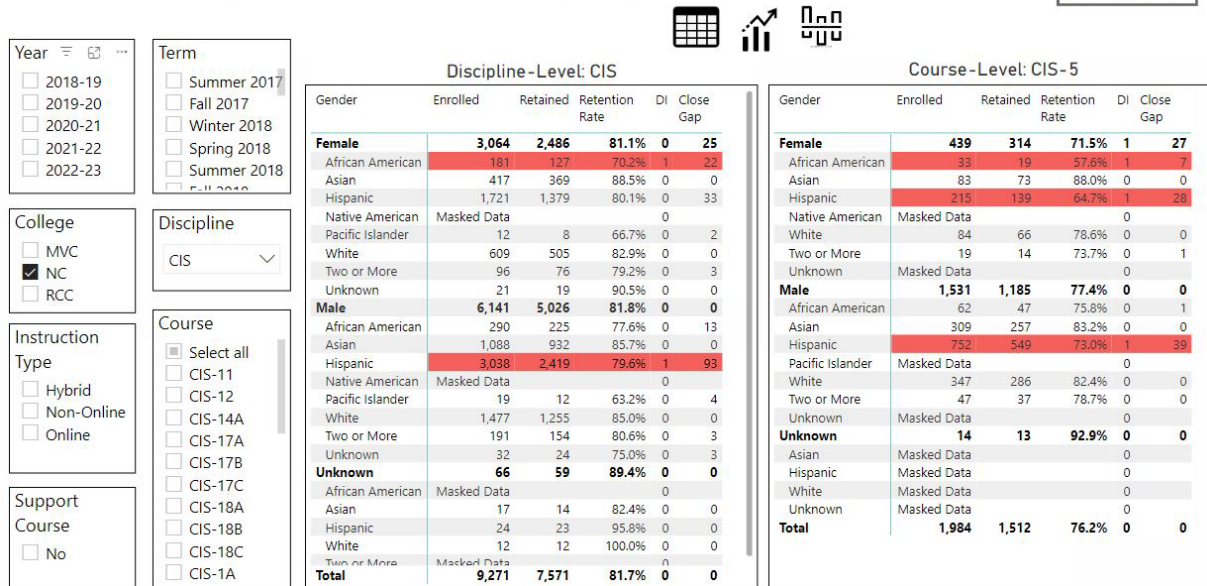| Gender	Enrolled	Success	Success Rate	DI	Close Gap
Female	**222**	**122**	**55.0%**	**0**	**0**
African American	23	8	34.8%	0	5
Asian	43	38	88.4%	0	0
Hispanic	107	49	45.8%	0	9
Native American	Masked Data			0	
White	37	22	59.5%	0	0
Two or More	11	5	45.5%	0	1
Unknown				0	
Male	**815**	**429**	**52.6%**	**0**	**15**
African American	42	18	42.9%	0	5
Asian	175	115	65.7%	0	0
Hispanic	411	192	46.7%	1	43
Pacific Islander	Masked Data			0	
White	148	83	56.1%	0	0
Two or More	31	18	58.1%	0	0
Unknown	Masked Data			0	
Unknown	**Masked Data**			**0**	
Asian	Masked Data			0	
Hispanic	Masked Data			0	
White	Masked Data			0	
Total	**1,043**	**553**	**53.0%**	**0**	**0**

CIS-5 Success and Retention

Because CIS-5, Introduction to Programming Methodology using C++, is the entry level high enrollment computer programming course, the success and retention data is presented apart from the overall CIS/CSC data.

The overall success rate for CIS-5 is 53% compared to 65.7% for overall CIS success rates. This is concerning particularly because in the previous 3 year time period the success rate for CIS-5 was trending up with a success rate of 64% in 2019-2020. This warrants further discussion among the CIS faculty particularly because CIS-5 is the foundational prerequisite course for other programming courses.

Retention Rates by Discipline & Course Disaggregated by Race/Ethnicity

Clear Selections

Discipline-Level: CIS

Gender	Enrolled	Retained	Retention Rate	DI	Close Gap
Female	**3,064**	**2,486**	**81.1%**	**0**	**25**
African American	181	127	70.2%	1	22
Asian	417	369	88.5%	0	0
Hispanic	1,721	1,379	80.1%	0	33
Native American	Masked Data			0	
Pacific Islander	12	8	66.7%	0	2
White	609	505	82.9%	0	0
Two or More	96	76	79.2%	0	3
Unknown	21	19	90.5%	0	0
Male	**6,141**	**5,026**	**81.8%**	**0**	**0**
African American	290	225	77.6%	0	13
Asian	1,088	932	85.7%	0	0
Hispanic	3,038	2,419	79.6%	1	93
Native American	Masked Data			0	
Pacific Islander	19	12	63.2%	0	4
White	1,477	1,255	85.0%	0	0
Two or More	191	154	80.6%	0	3
Unknown	32	24	75.0%	0	3
Unknown	**66**	**59**	**89.4%**	**0**	**0**
African American	Masked Data			0	
Asian	17	14	82.4%	0	0
Hispanic	24	23	95.8%	0	0
White	12	12	100.0%	0	0
Two or More	Masked Data			0	
Total	**9,271**	**7,571**	**81.7%**	**0**	**0**

Course-Level: CIS-5

Gender	Enrolled	Retained	Retention Rate	DI	Close Gap
Female	**439**	**314**	**71.5%**	**1**	**27**
African American	33	19	57.6%	1	7
Asian	83	73	88.0%	0	0
Hispanic	215	139	64.7%	1	28
Native American	Masked Data			0	
White	84	66	78.6%	0	0
Two or More	19	14	73.7%	0	1
Unknown	Masked Data			0	
Male	**1,531**	**1,185**	**77.4%**	**0**	**0**
African American	62	47	75.8%	0	1
Asian	309	257	83.2%	0	0
Hispanic	752	549	73.0%	1	39
Pacific Islander	Masked Data			0	
White	347	286	82.4%	0	0
Two or More	47	37	78.7%	0	0
Unknown	Masked Data			0	
Unknown	**14**	**13**	**92.9%**	**0**	**0**
Asian	Masked Data			0	
Hispanic	Masked Data			0	
White	Masked Data			0	
Unknown	Masked Data			0	
Total	**1,984**	**1,512**	**76.2%**	**0**	**0**

Year slicer: 2018-19, 2019-20, 2020-21, 2021-22, 2022-23
Term slicer: Summer 2017, Fall 2017, Winter 2018, Spring 2018, Summer 2018, Fall 2018
College slicer: MVC, NC (checked), RCC
Discipline slicer: CIS
Instruction Type slicer: Hybrid, Non-Online, Online
Course slicer: Select all, CIS-11, CIS-12, CIS-14A, CIS-17A, CIS-17B, CIS-17C, CIS-18A, CIS-18B, CIS-18C, CIS-1A
Support Course slicer: No

The overall retention rate for the CIS discipline is 81.7% which is improved from the previous years, however it is below the college average and below 88% which is the retention rate for CIS in Fall 2019. There is room for improvement.

CIS-5 retention rates are 76.2% which significantly lower retention rates for African American females, Hispanic females, and Hispanic males. Faculty are discussion strategies to address this disparity.

CIS-1A Success and Retention

Because CIS-1A (Introduction to Computer Information Systems) is an entry-level high-enrollment course, the success and retention data for CIS-1A is presented apart from the overall CIS data.

Success rates for CIS-1A are slightly higher than the overall CIS discipline rate, but still lower than the college average and lower than prepandemic rates. Areas of concern are success rats for Hispanic females and African American males.

Data Review

Success Rates by Discipline & Course Disaggregated by Race/Ethnicity

Discipline-Level: CIS

Gender	Enrolled	Success	Success Rate	DI	Close Gap
Female	**1,311**	**862**	**65.8%**	**0**	**0**
African American	69	36	52.2%	1	10
Asian	206	166	80.6%	0	0
Hispanic	730	443	60.7%	1	45
Native American	Masked Data			0	
Pacific Islander	Masked Data			0	
White	243	180	74.1%	0	0
Two or More	48	31	64.6%	0	1
Unknown	Masked Data			0	
Male	**2,848**	**1,871**	**65.7%**	**0**	**5**
African American	132	71	53.8%	1	17
Asian	556	413	74.3%	0	0
Hispanic	1,453	915	63.0%	1	62
Native American	Masked Data			0	
Pacific Islander	10	3	30.0%	0	4
White	583	394	67.6%	0	0
Two or More	98	66	67.3%	0	0
Unknown	14	8	57.1%	0	2
Unknown	**30**	**21**	**70.0%**	**0**	**0**
African American	Masked Data			0	
Total	**4,189**	**2,754**	**65.7%**	**0**	**0**

Course-Level: CIS-1A

Gender	Enrolled	Success	Success Rate	DI	Close Gap
Female	**636**	**438**	**68.9%**	**0**	**1**
African American	27	17	63.0%	0	2
Asian	78	62	79.5%	0	0
Hispanic	388	252	64.9%	1	22
Native American	Masked Data			0	
Pacific Islander	Masked Data			0	
White	115	88	76.5%	0	0
Two or More	20	16	80.0%	0	0
Unknown	Masked Data			0	
Male	**770**	**531**	**69.0%**	**0**	**0**
African American	41	18	43.9%	1	11
Asian	106	82	77.4%	0	0
Hispanic	416	291	70.0%	0	0
Native American	Masked Data			0	
Pacific Islander				0	
White	175	120	68.6%	0	1
Two or More	23	15	65.2%	0	1
Unknown	Masked Data			0	
Unknown	**10**	**7**	**70.0%**	**0**	**0**
African American				0	
Total	**1,416**	**976**	**68.9%**	**0**	**0**

Retention rates for CIS-1A have rebounded to prepandemic levels with an average of 83.6%. No red flags appear when disaggregated for gender, race or ethnicity.

Retention Rates by Discipline & Course Disaggregated by Race/Ethnicity

Discipline-Level: CIS

Gender	Enrolled	Retained	Retention Rate	DI	Close Gap
African American	69	45	65.2%	1	12
Asian	206	185	89.8%	0	0
Hispanic	730	582	79.7%	0	20
Native American	Masked Data			0	
Pacific Islander	Masked Data			0	
White	243	207	85.2%	0	0
Two or More	48	38	79.2%	0	2
Unknown	Masked Data			0	
Male	**2,848**	**2,336**	**82.0%**	**0**	**0**
African American	132	103	78.0%	0	6
Asian	556	479	86.2%	0	0
Hispanic	1,453	1,163	80.0%	1	42
Native American	Masked Data			0	
Pacific Islander	10	6	60.0%	0	3
White	583	491	84.2%	0	0
Two or More	98	82	83.7%	0	0
Unknown	14	11	78.6%	0	1
Unknown	**30**	**27**	**90.0%**	**0**	**0**
African American	Masked Data			0	
Asian	10	10	100.0%	0	0
Hispanic	Masked Data			0	
White	Masked Data			0	
Two or More	Masked Data			0	
Unknown	Masked Data			0	
Total	**4,189**	**3,431**	**81.9%**	**0**	**0**

Course-Level: CIS-1A

Gender	Enrolled	Retained	Retention Rate	DI	Close Gap
Female	**636**	**535**	**84.1%**	**0**	**0**
African American	27	22	81.5%	0	1
Asian	78	70	89.7%	0	0
Hispanic	388	320	82.5%	0	7
Native American	Masked Data			0	
Pacific Islander	Masked Data			0	
White	115	99	86.1%	0	0
Two or More	20	18	90.0%	0	0
Unknown	Masked Data			0	
Male	**770**	**640**	**83.1%**	**0**	**9**
African American	41	30	73.2%	0	5
Asian	106	96	90.6%	0	0
Hispanic	416	344	82.7%	0	6
Native American	Masked Data			0	
Pacific Islander				0	
White	175	143	81.7%	0	4
Two or More	23	21	91.3%	0	0
Unknown	Masked Data			0	
Unknown	**10**	**9**	**90.0%**	**0**	**0**
African American				0	
Asian	Masked Data			0	
Hispanic	Masked Data			0	
White	Masked Data			0	
Two or More	Masked Data			0	
Total	**1,416**	**1,184**	**83.6%**	**0**	**0**

Program Awards

Computer Science

The number of program awards for Computer Science continues to increase, with the exception of the 20-21 academic year. The addition of the ADT Computer Science is likely contributing to the increase.

Computer Programming Certificate

The number of students completing the certificate in Computer Programming remains low. In the past there are a large number of students who declare this certificate as a program of study but do not follow through, or perhaps the institution is not capturing the data. Students may take a few courses and then leave to join the workforce without the need to complete the certificate. It would be interesting to dig deeper and determine if this certificate is providing students with meaningful skills.

Please add any relevant documents here.

Disaggregated Student Subgroups

Look at the disaggregated student subgroups in success, retention, program of study, educational planning, and awards for your area. Are there any equity gaps that you will address in the next 3 years?

As indicated in the Overal Trends report, areas of concern are African American females, African American males, Hispanic females and Hispanic males.

Yes, we will attempt to address the equity gaps with the support of the institution.

If there are any concerning trends over the past 3 or more years, or if equity gaps exist, what is your action plan to address them?

The plan of action is to work with the institution to recruit more females and African American students into CIS programs of study. Faculty can then address retention and succes rates in a variety of ways including highlighting contributions by femails and African American computer scientists, encouraging outside support such as tutoring in the LRC and embedded tutors in online classes. Faculty will continue to educate themselves on equity minded practices.

Please add any relevant documents here.

Program Awards (EMP Goal 2, Objective 2.1)

Program/Unit Goal
Increase number of degrees completed annually in Computer science (EMP Goal 2, Objective 2.1)

Goal Cycle
2024 - 2027

What are you doing now in support of this goal?
The department recognizes that many students have professional and family obligations that conflict with traditional college schedules and make it difficult for these students to complete a course of study. The department has been working to increase flexibility of student schedules and access to classes by increasing the number of offered hybrid and online courses to allow students to access classes more easily and thereby increase accessibility of classes to students and encourage degree completion. Trends seem to suggest significant success within this approach, as the number of Computer Science degrees has risen in correspondence with the number of hybrid and online classes available.

What are your plans (3-year) regarding this goal?
The department is planning to investigate offering an increased number of hybrid and online classes along with investigating options for ZCT (zero cost textbook) class offerings to increase course accessibility and degree completion to a wider range of students.

Please add any relevant documents here.
Awards.png

Mapping
Educational Master Plan (2020-2025): ( )
* 2025 Objective 2.1 - KPI 4 (Academic Affairs):

Evidence

Evidence Date
03/22/2024

Please provide any assessment data or other evidence that supports this Program/Unit Goal.
The program awards data shows a significant increase in program completion and the number of degrees awarded for Computer Science over the assessment period.

Is there a resource request associated with this Goal?
No

If yes, please provide a short description.

Please add any relevant documents here.
Awards.png

Program Awards (EMP Goal 2, Objective 2.2)

Program/Unit Goal
Increase number of certificates completed annually in Computer science (EMP Goal 2, Objective 2.2)

Goal Cycle
2024 - 2027

What are you doing now in support of this goal?

The department recognizes that many students have professional and family obligations that conflict with traditional college schedules and make it difficult for these students to complete a course of study. The department has been working to increase flexibility of student schedules and access to classes by increasing the number of offered hybrid and online courses to allow students to access classes more easily and thereby increase accessibility of classes to students and encourage certificate completion. There is an upward trend in certificates obtained which seems to indicate certificate completion has increased in correspondence with the number of hybrid and online classes available. Recently Norco College has also adopted the Python Programming Certificate in Computer Science expanding the number of potential certificates that can be completed and offering additional options to students.

What are your plans (3-year) regarding this goal?
The department is planning to investigate offering an increased number of hybrid and online classes along with investigating options for ZCT (zero cost textbook) class offerings to increase course accessibility and certificate completion to a wider range of students.

Please add any relevant documents here.
Awards.png

Mapping
Educational Master Plan (2020-2025): ( )
- 2025 Objective 2.2 - KPI 5 (Academic Affairs):

Evidence

Evidence Date
03/22/2024

Please provide any assessment data or other evidence that supports this Program/Unit Goal.
The assessment report shows a general increase in the number of certificates awarded.

Is there a resource request associated with this Goal?
No

If yes, please provide a short description.

Please add any relevant documents here.
Awards.png

2024 - 2027

1. Which equity-related professional development trainings have members of your area participated in to improve student learning, student support, and/or college support?

Members of the CIS Discipline have completed a number of equity related trainings and certifications. Through CORA, certifications were obtained in: Black Ally Program - Dismantling Anti-Blackness on Your Campus, Black Minds Matter, and Racial Microaggressions. Faculty members have also attended several of the CCCAOE (California Community College Association for Occupational Education) which has a number of rich sessions focused on equity and bridging equity gaps. All Faculty members were in attendance of the Achieving Equity in Guided Pathways summit lead by keynote speaker Dr. Rob Johnstone (September 14th and 15th, 2023). Aside from trainings, we also have one Faculty member representative that serves on the LGBTQ+ Advocates committee, a group that emphasises equity and fair representation at Norco College

2. What knowledge or skills/techniques have members in your area implemented from these trainings and what changes have you seen?

The discipline is encouraging the adoption of zero cost textbook courses where it is pedagogically sound. Reducing the cost reduces a barrier to take a course. Highlighting non-male and African American contributions to the field lets students see themselves in these roles. Recruiting tutors with diverse ethncities to support student success is another technique. Understanding micro-agressions and addressing any in the classroom supports an inclusive classroom environment.

3. What additional equity-related professional development/trainings do you seek to better support your area?

None come to mind.

Please add any relevant documents here.

2024 - 2027

Are all your courses current (within four years)?

No

What percentage of your courses are out of date?

More than 25%

If you have courses that are not current, are they in the curriculum process?

No

For out of date courses that are not already in progress of updating, what is your plan?

Ten CIS courses have not been updated since 9/1/2020. In all instances the updates require book updates. Faculty are discussing a plan to address the update plan.

Do you have proposals in progress for all the DE courses you intend to file?

No

Do you require help to get your courses up to date?

No

Please add any relevant documents here.

Screenshot 2024-03-22 at 3.17.02 PM.png

Outcome Mastery

Date
03/20/2024
Observation
What did you notice?
SLO_2 had a low mastery level which demonstrates a slight upward trend over time.
Course(s)
CIS-18A
SLO(s)
CIS-18A_SLO-2
Demonstrate an understanding of the fundamentals of object-oriented development sufficient to create and use classes as the foundation of Java application programs.

Discussion/Analysis
Students demonstrate a low mastery level in CIS-18A SLO#2 which relates to object-oriented programming in Java. However, students are also achieving a high mastery level in SLO#1 relating to functional programming in a Java IDE. This suggests that a higher emphasis should be placed on object-oriented concepts in CIS-18A. However, data shows an upward trend in mastery level for this SLO, which may indicate that adjustments to the course are already having a positive effect on SLO#2. The department should take into account outcome data related to this SLO and assess whether or not additional changes need to be made.
Please paste any relevant screenshots here.
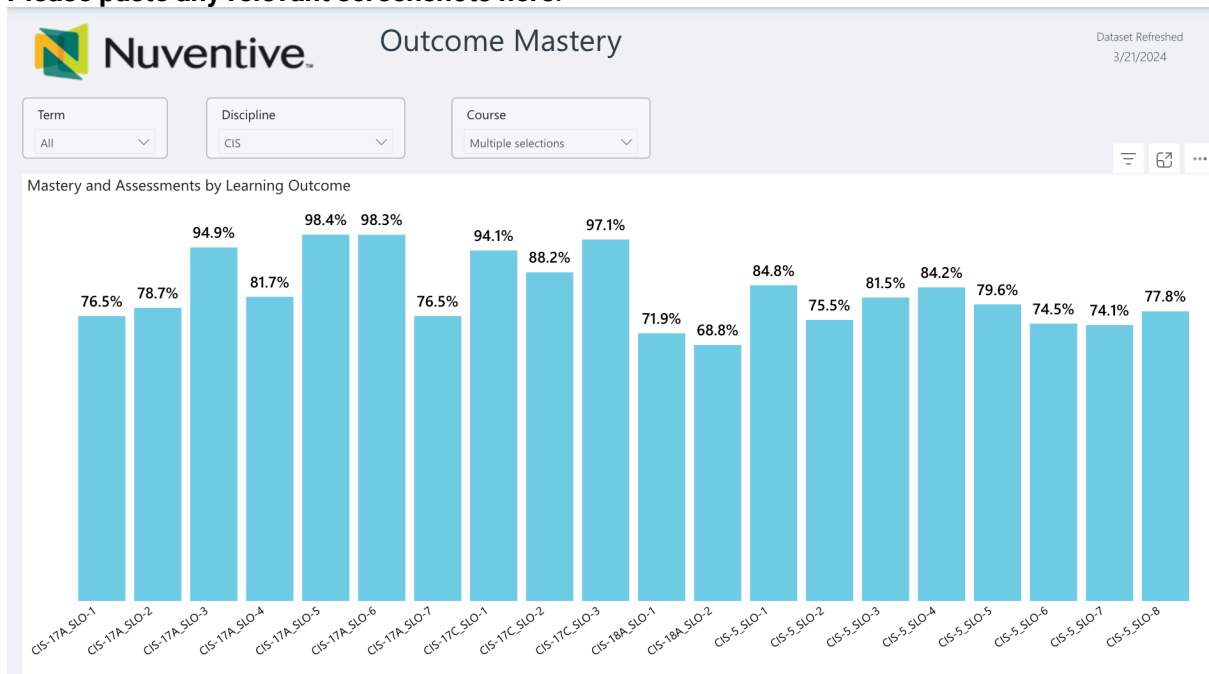
Please add any relevant documents here.

Outcome Mastery by Demographics

Date
03/20/2024
Observation
What did you notice?
There are some gaps evident in gender/age/ race/ethnicity subgroups
Course(s)

This observation refers to the entire discipline and doesn't go down to course- or SLO-level.

SLO(s)

This observation refers to the entire discipline and doesn't go down to course- or SLO-level.

Discussion/Analysis

The data demonstrates that there is a gap in outcome mastery among genders, with the most significant gap being demonstrated by non-binary students. However, this gap is affected by the low sample size of non-binary students and therefore the data for this particular subgroup is inconclusive. Between female and male students, there is almost no statistical difference in outcome mastery, indicating that the department should focus on closing demographic gaps in other areas and increasing sample size for more conclusive analysis. The data also demonstrates some gap in outcome mastery between different age groups. The data demonstrates a smaller gap in students ages 19 and below, which may indicate that concurrent enrolled students achieve a high level of mastery. Students ages 20-24 demonstrate a larger gap, with the gap decreasing significantly in students ages 25-29 and 30-34. The gap then increases significantly for students ages 35-49. This may suggest that students entering Norco college after high school achieve a lower master level than students who started classes at Norco while concurrently enrolled. The data demonstrates that there is a gap in outcome mastery among race/ethnicity. However, there are many groups with significantly small sample sizes, which renders the data largely inconclusive.

Please paste any relevant screenshots here.
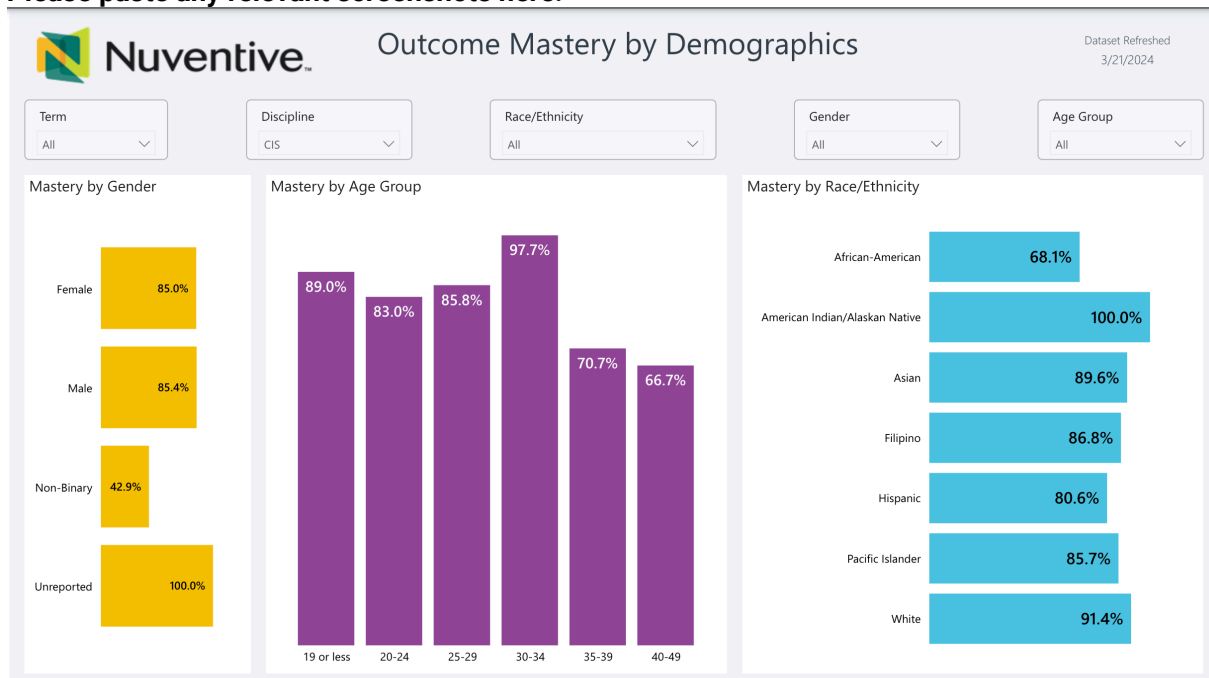
Please add any relevant documents here.

Outcome Mastery by Demographic.png

Faculty Professional Development Requests

Faculty Hiring Resource Requests

Reflections and Submission

Discipline

- [ ] ANT
- [ ] APP
- [ ] ARA
- [ ] ARE
- [ ] ART
- [ ] ASL
- [ ] BIO
- [ ] BUS
- [ ] CAT
- [ ] CHE
- [ ] CHI
- [x] CIS
- [ ] COM
- [ ] CON
- [ ] CRP
- [ ] CSC
- [ ] DAN
- [ ] DFT
- [ ] EAR
- [ ] ECO
- [ ] EDU
- [ ] ELC
- [ ] ELE
- [ ] ENE

Course	All ⌄
Year	All ⌄
Last Editor	All ⌄
Modification Type	All ⌄

Course	Last Updated	Last Editor	Status	Modification Type
CIS 17A	04/30/23	Mark Lehr	Active	Course Minor Modification
CIS 17B	04/30/23	Mark Lehr	Active	Course Minor Modification
CIS 17C	04/30/23	Mark Lehr	Active	Course Minor Modification
CIS 18A	04/30/23	Paul Conrad	Active	Course Major Modification
CIS 18B	04/30/23	Paul Conrad	Active	Course Major Modification
CIS 18C	04/30/23	Paul Conrad	Active	Course Major Modification
CIS 5	04/30/23	Mark Lehr	Active	Course Minor Modification
CIS 63	04/30/23	Mark Lehr	Active	Course Major Modification
CIS 7	04/30/23	Mark Lehr	Active	Course Minor Modification
CIS 80	04/30/23	Janet Lehr	Active	Course Minor Modification
CIS 90	04/30/23	Janet Lehr	Active	Course Minor Modification
CIS 93	04/30/23	Janet Lehr	Active	Course Minor Modification
CIS 98A	04/30/23	Janet Lehr	Active	Course Minor Modification
CIS 98B	04/30/23	Janet Lehr	Active	Course Minor Modification
CIS 30A	05/01/22	Kasey Nguyen	Active	Course Major Modification
CIS 30B	05/01/22	Kasey Nguyen	Active	Course Major Modification
CIS 30C	05/01/22	Kasey Nguyen	Active	Course Major Modification
CIS 30D	05/01/22	Kasey Nguyen	Active	Course Major Modification
CIS 30E	05/01/22	Kasey Nguyen	Active	Course Major Modification

Courses Not Updated Since 09/01/2020

10
Courses

Course	Last Updated
CIS 12	05/05/20
CIS 2	03/13/19
CIS 200	09/23/18
CIS 21	03/13/19
CIS 44	07/01/15
CIS 59	07/01/15
CIS 66	06/09/13
CIS 77	07/25/18
CIS 78B	03/13/19
CIS 81	03/13/19

Pair-Programming Helps Female Computer Science Students

LINDA L. WERNER, University of California, Santa Cruz
BRIAN HANKS, Fort Lewis College, Durango, Colorado
CHARLIE MCDOWELL, University of California, Santa Cruz

Pair-programming has been found to be very beneficial in educational settings. Students who pair in their introductory programming course are more confident, have greater course completion and pass rates, and are more likely to persist in computer-related majors. Although pairing helps all students, we believe that it is particularly beneficial for women because it addresses several significant factors that limit women's participation in computer science. We provide reasons for our belief that pair-programming helps women persist in these majors. We also repeat, with special emphasis on the impact on women, some details published elsewhere regarding our experiments on pair-programming with college and university students. Additionally, we provide new data that supports our original findings.

Categories and Subject Descriptors: K.3.2 [**Computers and Education**]: Computer and Information Science Education

General Terms: Experimentation, Human Factors

Additional Key Words and Phrases: Pair programming, collaboration, gender

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1. INTRODUCTION

A 2000 UCLA survey of over 400,000 entering freshman at 717 colleges and universities across the US reported the largest confidence gender gap in computer skills in the 35-year history of the survey. The gender gap in computer use was almost non-existent (79.5% men and 77.8% women reported frequent computer use); however, only 23.2% of the women versus 46.4% of the men rated their computer skills as "above average" or within the "top 10 percent." Also, 9.3% of the men versus 1.8% of the women reported intent to pursue computer programming careers [Sax 2000]. This computer science gender gap has been extensively written about and, unfortunately, has been widening [Camp 1997; 2001In 2004, 65% of the SAT I test takers had completed computer literacy-related course work or experience. The majority (55%) of these students were women, yet when narrowed to course work or experience in computer programming, the percentage of women dropped to 40%. In addition, of the 5% of the 2004 SAT I test takers who intended to major in computer or information science once in college, only 14% were women [College Entrance Examination Board 2004].

As reported by the Computing Research Association (CRA), little change has occurred during the years from 1993/1994 to 2002/2003, when less than 20% of the computer engineering/computer science BS degrees were awarded to women in each of those years.

During that same period, when gender data is available from the National Science Foundation (NSF), the percentages of science and engineering BS degrees granted to women has steadily increased, with the percentage of women at 50% in the years 2000/2001 [CRA 2005]. Even the most mathematically talented women favor medicine and law over careers in information technology because they perceive those professions as more socially meaningful and interactive [Lightbody et al. 1997]. This is consistent with the AAUW [2000] report that girls are not avoiding high-tech careers because they are failing in them. Rather, the AAUW report identifies the following reasons why fewer women are majoring in computer science (CS):

(1) the widely held perception that a career in computing is not well-rounded or conducive to family life;

(2) the belief that work in the information technology field is conducted in a competitive rather than collaborative environment;

(3) the perception of CS as a solitary occupation that is not well integrated into social discourse or social institutions; and

(4) concerns about safety and security reported by women and their friends and families about working alone at night and on weekends in computer laboratories.

We propose that using pair-programming in college and university CS courses could address three of the reasons why fewer women major in CS; we also have suggestions for removing the last of the four reasons. We present promising results from three studies regarding the use of pair-programming in beginning programming courses. These findings show that students who pair-programmed were more confident in their programming solutions and enjoyed completing the assignments more than students who programmed alone. Paired students were more likely to complete the course, and consequently to pass it. Results have been published regarding a primary study of over 500 mostly residential students in introductory programming courses at the University of California, Santa Cruz (UCSC) [McDowell et al. 2003]. We report here previously unpublished findings regarding a repeat of this study, with over 200 students at two additional institutions of higher education: San Jose State University (SJSU) and Cabrillo College, both commuter campuses. We found that the new findings mirror those at UCSC regarding confidence and pass rates. Due to smaller populations, we do not have statistically significant results in most of the areas for the subset of women at the two commuter campuses. We refer to this second experimental group as the secondary study. We also report on an additional group of UCSC students from the 2003-2004 academic year, which we refer to in this paper as the tertiary study.

Paired students performed as well on final exams taken individually as solo students did. For the primary study, we also looked at whether students continued to register as CS-related majors one year later. We found that paired students were more likely to persist in this major. Significantly more paired women programmers than solo women programmers went on to declare a CS-related major [McDowell et al. 2003]. Hence we claim that pair-programming holds promise for closing the gender gap in CS.

2. WHAT IS PAIR-PROGRAMMING AND HOW CAN IT BE USED IN EDUCATION?
Essentially all non-trivial software projects are created collaboratively. Almost all professional programmers have, on occasion, worked with another colleague on one computer to debug a program that didn't work as expected. This informal process involving two collaborators using a single computer has been formalized as pair-programming, and

become widely known because it is a key practice of the extreme programming (XP) development methodology [Beck 2000].

In XP, all software is designed, developed, and tested using pair-programming. While pairing, one of the programmers, referred to as the "driver," controls the keyboard and mouse and is responsible for entering program code. The second programmer, known as the "navigator," sits next to the driver and watches for errors, discusses alternative design approaches, and offers suggestions. The programmers regularly trade roles while pairing. Two goals of pair-programming are to have all code created collaboratively by the pair and to have the pair collectively "own" the code. Code written by only one member of the pair is reviewed by both partners together before it is officially accepted as part of the program.

Traditional undergraduate introductory programming courses generally require that students work individually on their programming assignments. In these courses, working with another student on a homework programming assignment constitutes cheating and is not tolerated. The only resources available to help students overcome problems that they may be having are the course instructor, the textbook, and the teaching assistant. Students are not allowed to work with their peers, who are also struggling with the same material. A female student interviewed by Berenson et al. [2005] observed that "you have to do all this stuff on your own and there's nobody to talk to and to ask a question to." This pedagogical approach teaches students that software development is an individual activity, thus possibly giving students the mistaken impression that software engineering is an isolating and lonely career.

Collaborative methods are often used in upper-division computer science courses such as compiler design or software engineering in which group projects are encouraged or mandated. A software engineering instructor will sometimes offer assistance to the student groups regarding techniques for collaboration. One example is the research on agile processes, including pair-programming in software engineering courses at NCSU [Berenson et al. 2005]; but the topic of collaboration is rarely discussed in other CS courses.

By deferring collaborative exercises to the upper-division courses, we believe that many CS departments are losing female students who are interested in computer science but became discouraged by its focus on individual, socially isolating work. As reported by Berenson et al. [2005], a female student "said she had been taking computer science courses for three years and did not know anyone in her classes." This changed when she began to pair-program.

We recommend requiring students to pair-program in all introductory programming courses. We introduce our students to pair-programming by having them read "All I Really Need to Know About Pair Programming I Learned In Kindergarten" [Williams and Kessler 2000a]. Additionally, we have published pair-programming implementation guidelines that we derived during our primary study [Bevan et al. 2002]. One of us (Hanks) also uses the "pair-draw" exercise to help students appreciate the benefits of pairing [Kerievsky 2004].

3. HOW DOES PAIR-PROGRAMMING LEAD TO WOMEN PERSISTING IN CS?

In the 2000-2001 academic year, 555 students (141 women, 413 men, and 1 whose gender was not reported) participated in a study on pair-programming at UCSC. We studied four sections of our introductory programming course which were taught by three different instructors. In three of the sections, students pair-programmed; in the fourth they worked individually. The instructor of the solo section also taught one of the paired sections, and is a co-author of this paper (McDowell). The statistics summarized here were collected as

part of that study and reported in McDowell et al. [2003]. There was no significant difference between the pairing and non-pairing students with regard to high school GPA, transfer GPA, or SAT math scores.

We wanted to answer several questions with our study; one was "Are women who pair-program in their introductory programming course more likely to complete and pass the course?" Our definition of course completion is that the student took the final exam; to pass the course, a student had to receive a grade of "C" or better.

A comparison of paired and solo women (101 versus 39) showed that those who paired were more likely than those who worked alone to complete the course (88.1% versus 79.5%, $p = .19$). The 8 percentage point difference in completion rate is practically significant although not statistically significant. For men, a 10 percentage point difference in completion rates between the paired and solo students was significant (91.7% versus 81.5%, $p < .05$). Although the increase in completion rates was similar for women and men, the lack of statistical significance for the women can be explained by the much smaller number of women in our study (140 women compared with 411 men). Among those who completed the course (by taking the final exam), the difference in pass rates between paired and solo programming students was not statistically significant (79.6% versus 78.2%); statistics from our secondary study validate these findings. A comparison of paired and solo women (13 versus 20) shows that those who paired were more likely than those who worked alone to complete the course (92.3% versus 75.0%, $p = .21$). The 17 percentage point difference is practically significant but not statistically significant. For men, a 15 percentage point difference between the paired and solo students was significant (85.1% versus 69.9%, $p < .05$). Among those who completed the course (by taking the final exam), the difference in pass rates between paired and solo programming students was not statistically significant (79.1% versus 87.9%, $p = .15$). However, using our terminology, it can be said that it is practically significant that more of the solo completers passed the class. If we look at all of the students, significantly more of the paired students than solo students passed the course (66.0% versus 52.3%, $p < .05$).

Further evidence that female students who pair-program perform better is provided by data collected in three additional sections of our introductory programming course as part of the tertiary study conducted by a co-author of this paper (Hanks). All students in these courses paired. Of the 24 female students who participated in the study, 23 (95.8%) took the final exam, and 21 passed the course (91.3%). Similar rates were seen for men. Of the 91 men enrolled in the three sections of the course, 85 (93.4%) took the final exam and 78 passed the course (91.8%) These rates are comparable to or better than those reported in our primary study.

Our second question concerns retention in CS-related majors. We wanted to know if pair-programming in the introductory classes led to increased numbers of women persisting in CS. We followed students in our primary study for one full academic year after the introductory programming course. We only followed students who had passed the course with a "C" or better. Our sample size was decreased further by students leaving UCSC. Furthermore, the numbers reported here only include students who stated on the first day of the introductory class that their major (or intended major) was in CS or a CS-related field. Even though our introductory programming course was primarily intended for CS or CS-related majors, the class included students majoring in a wide variety of fields. For this part of our analysis, our sample size was 237 (51 women, 186 men). A significantly higher percentage of the students who paired in the introductory course attempted the subsequent programming course required for CS-related majors (76.7% versus 62.2%, $\div 2(1) = 6.17$, $p < .05$). A separate analysis by gender revealed an

18.2% difference for paired versus solo women (73.8% versus 55.6%). The increase in attempt rates by women who paired over solo women was not statistically significant ($\div2(1) = 1.19$, $p = .27$), even though the same approximate difference (18.6%) in attempt rates was seen for paired men versus solo men, and was statistically significant (88.0% versus 69.4% $\div2(1) = 7.60$, $p < .01$). Again, the lack of statistical significance for the data on women is probably attributable to their relatively small numbers in this part of the analysis.

Among the students in our study who attempted the second course (which did not use pair-programming), we found no significant difference in pass rates between paired and solo students. Thus, more students who paired passed the introductory course, more of these students attempted the second course, and this larger pool of students passed the second course at similar rates to those who worked alone in the introductory course.

As a second measure of retention, we wanted to know if the paired women students were more likely to declare a CS-related major one year after completing the introductory programming course. We found that 59.5% of the female potential CS-majors who paired declared a CS-related major one year later, compared with only 22.2% of the women who worked alone. This result is both practically and statistically significant ($\div2(1) = 4.14$, $p < .05$). Men who paired were also more likely to have declared a CS-related major one year later than those who worked individually (74% versus 47.2%, $\div2(1) = 9.70$, $p < .005$). The same pattern was seen for our students who successfully completed the introductory programming class and were still enrolled at UCSC one year later, *regardless* of what major (or no major) they declared on the first day of the introductory course.

The potential impact of the increased retention rate on the gender gap can be seen by looking at a hypothetical example. Assume that there are 100 potential computer science majors (50 women, 50 men) enrolled in an introductory programming course. If these students worked alone, one year later there would be 35 declared majors, 31% of whom are female (22.2% of 50 women and 47.2% of 50 men). If these students paired, then one year later there would be 67 declared majors, 45% of whom are female (59.5% of 50 women and 74% of 50 men).

Another area of concern was the potential impact of pair-programming on student confidence. We believe that students who are confident of their computing abilities will be more likely to pursue studies in those areas. As part of our study, we asked students to complete a short questionnaire when they turned in each of their programming assignments. To assess student confidence levels, we asked them to respond to the following question: "On a scale from 0 (not at all confident) to 100 (very confident), how confident are you in your solution to this assignment?"

Overall, students who paired reported significantly higher confidence in their program solutions than students who worked independently (89.4 versus 71.2, $p < .001$). This is consistent with the findings from interviews of female students by Berenson et al [2005]. Although as a group all the men were significantly more confident than all the women (87.0 versus 81.1, $p < .001$), there was a significant interaction between pairing and gender with regard to reported confidence. Simple follow-up tests of the interaction indicated that pairing resulted in increased confidence for both women (86.8 versus 63.0, $p < .001$) and men (90.3 versus 74.6, $p < .001$). We also found that the gender of a student's partner was unrelated to the confidence level of that student. Women's confidence increased by 24 points when they paired, compared with a 15 point increase for men. It appears that pairing has a greater effect on confidence levels for women, and therefore may have a visible, positive impact on the gender gap. Unpaired men reported 1.18 times greater confidence

than unpaired women, while paired men reported 1.04 times greater confidence than paired women. Pairing seems to close the confidence gap between women and men.

Similarly, for our secondary study, paired women reported greater confidence levels than unpaired women (83.2 versus 72.6, $p = .31$), but this increase in reported confidence is not statistically significant, probably due to the small sample size ($n = 22$). The average reported confidence level for all paired students in our secondary study was 86.6 versus the average reported confidence level for all unpaired students of 76.0. This difference is significant with $p < .005$.

We asked participants in our tertiary study at UCSC (in which all students were paired), to answer the same question pertaining to confidence. We found that these paired students exhibited similar levels of confidence as the paired students in our original study. In the more recent study, the average confidence level for all students was 88.7; it was 88.8 for men, and 88.3 for women. The results from our secondary and tertiary studies add weight to our earlier finding that students who pair are more confident in their work and that the gender gap in confidence is diminished with pair-programming.

4. WHY DOES PAIR-PROGRAMMING LEAD TO WOMEN PERSISTING IN CS?

Women's belief about the solitary nature of computer science is confirmed when they enroll in an introductory programming course that requires programming assignments to be done individually. Instead, when pair programming is used, it is possible that women view programming as a collaborative exercise. Williams and Kessler suggest that "peer pressure" may be at work as a possible explanation for higher completion rates among paired vs. solo programming students [Williams and Kessler 2000a]. It may be the collaborative aspect of pair programming that is a major reason that the students remain in the class. The increased levels of confidence that can be attributed to pairing are probably also a factor in improved retention.

It is important to us not only that women stay in the class but that they pass at similar rates to men. Given that the exams are taken individually, the paired students are mastering the course material at the same rates as the solo students. Additionally, if a "pair-oriented culture" is encouraged by having short discussion periods during class time, then women might question their belief that work in the information technology is conducted in a competitive rather than collaborative environment. They might also question their perception of CS as a solitary occupation that is not well integrated into social discourse or social institutions. Another serendipitous outcome of pair-programming is that no one works alone late at night or on weekends in a computer laboratory. Partners work together. We hypothesize that for the reasons given above, pair programming contributes to women persisting in CS.

One reason not addressed by pair programming as to why fewer women major in computer science (as stated in the AAUW report) remains. The report states that women believe that a career in computing is not well-rounded or conducive to family life. An effort needs to be made by the authors of introductory programming textbooks to create exercises and examples that "highlight the human, social, and cultural dimensions and applications of computers rather than the technical advances, the speed of the machines or the entrepreneurial culture surrounding them" [AAUW 2000, p. 10]. There seems to be some hope for such an outcome: The recent Java textbook by Cohoon and Davidson [2004] includes programming exercises and examples drawn from fields such as medicine, personal finance, health and fitness, and data visualization. We are encouraged by this, and hope that other authors follow this lead.

5. CONCLUSIONS

Pair-programming is shown to be beneficial to all students. We argue that it is particularly beneficial for women because it addresses factors that potentially limit their participation in CS. The collaborative nature of pair-programming teaches women students that software development is not the competitive, socially isolating activity that they imagined. It encourages women to pursue computer science as a major and as a potential career. Because of this, we strongly advocate the use of pair-programming in all introductory programming courses. We are now using pair-programming in all introductory programming courses we teach. Additionally, we use optional pair- programming in all upper-division programming courses we teach. The teachers who experimented with pair-programming for the secondary study all strongly believe in it and encourage their students to use it. We suggest you try it too!

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Degrees

Gender x Ethnicity	18-19	19-20	20-21	21-22	22-23	Total
Female	3	4	3	2	5	17
Asian	1	1	1		2	5
Hispanic/Latino	1	2	1	2	1	7
White	1	1	1		2	5
Male	7	8	8	26	21	70
Asian	1	2	4	7	4	18
Hispanic/Latino	3	1	4	12	14	34
Unknown/Unreported					1	1
White	3	5		7	2	17
Unreported				1	1	2
Asian				1	1	2
Total	10	12	11	29	27	89

Certificates

Gender x Ethnicity	18-19	19-20	20-21	21-22	22-23	Total
Female		1	2	1	2	6
Asian			1		1	2
Hispanic/Latino				1	1	2
White		1	1			2
Male	2	2	3	2	3	12
Asian				1	1	2
Hispanic/Latino	1	1	1		2	5
White	1	1	2	1		5
Total	2	3	5	3	5	18