Computer Science and Gender:

National Issues Applied to the University of Colorado

Rachel Schoenbauer

Bachelor of Science -Computer Science

Bachelor of Arts – Theatre

ATLAS - Technology and Media Certified

Introduction:

The University of Colorado College of Engineering and Applied Science Department of Computer Science can be considered one of the best in the state. The rich environment of Boulder with its college town atmosphere mingling with the cutting edge of the professional world and an older population makes for a unique learning experience quite unlike any other university.

One unfortunately similarity with computer science programs (CS) around the nation is the low percentage of women participating within the CS major. The computer science department at the university has fewer than 10% women participation, lower than the rest of the College of Engineering and Applied Science by 11%.

There are copious amounts of literature based on discovering and implementing changes in curriculum, program, and community to benefit computer science women. Some of these issues applied in research solely to female students, however, can be more universally applied to both genders within computer science and the techniques implemented at other colleges and universities to boost retention and improve teaching could be applied at the University of Colorado (CU) with the increase of female students in computer science a serendipitous side effect of diversifying the curriculum, adopting a holistic teaching style, providing support for the students and strengthening the community.

Part I: The Numbers

Computer science is the study of the theoretical foundations of information and computation and their implementation and application in computer systems. An expanded definition requires computer science to include the systematic study of computing systems. The term computer science incorporates the body of knowledge resulting from the discipline, which contains theories for understanding computing systems and methods; design methodology, algorithms, and tools; methods for the testing of concepts; methods of analysis and verification; and knowledge representation and implementation. The field of computer science is evolving at a rapid rate, so what is precisely meant by 'computer science' is not easily pinned down.

This ambiguity in the definition of computer science allows colleges and universities to locate departments of computer science in whichever area the institution sees fit. This means that colleges, like Roosevelt University in Chicago [21], have computer science with stronger ties to Arts and Sciences, while colleges like the University of Colorado have their offices among the engineers. Additionally, some institutions classify their information technologies and digital media within the realm of computer science, teaching related classes as part of the curriculum. Professor of Engineering David Lorge Parnas, for example, advocates for the separation of Software Engineering from Computer Science as a whole [22], which would make classification even more difficult.

The various inclusions in the definition of computer science makes the quantitative tracking of students participating in, transferring and graduating out, and pursing as a career difficult. If, for example, Princeton [24] and its research-oriented department were compared to the numbers for the University of Colorado and the

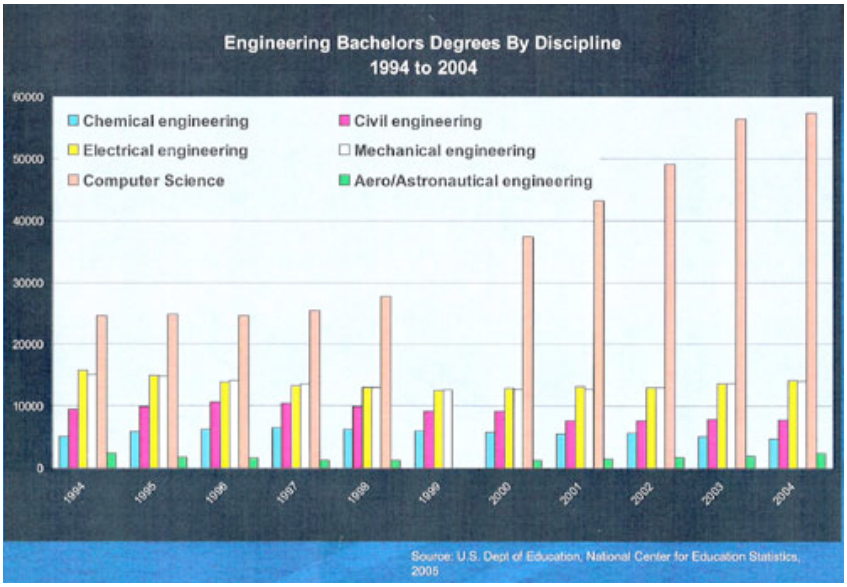
percentage of females within the Computer Science in Engineering program, then CU would fall short because the digital media and design instruction is associated with ATLAS and thus not counted among the Computer Science study numbers. For example, the Engineering Workforce Data deals specifically with engineering and ATLAS students are not necessarily tallied as engineers. Focus on digital media and other design-based teaching methods are described by Alice Agogino and Marcia Linn as one of the ways women can be and are retained within computer science [1]. The lack of design-based classes within computer science affects the retention of women has been described by Elizabeth Jessup and Tamara Sumner [18], and the inclusion of design classes within the data for some computer science programs makes comparing individual colleges difficult, regardless of guidelines set in place by data collection agencies.

Despite the non-uniformity of the data, studies and articles lament the lack of women in computer science, both in the total number of females graduating with bachelors and the total number of females declaring CS as a freshman. Tracy Camp commented in 1997, "The percentage of bachelor's degrees awarded in CS to women decreased almost every year over the last decade" [5]. A more recent paper by Juan Gilbert appears to show quite the opposite: The percentage of entering freshmen declaring computer science is following a downward trend [14]. However, Gilbert's data ends in 2002 and only refers to the percentage of freshmen intending to enter into computer science. Figure one also reflects the 1998 peak in freshman interest and figure two illustrates the 2004 peak that corresponds to the peak in interest. So, at least until 2004, the number of computer scientists was increasing, despite newspaper articles titled, "Where'd the Whiz Kids Go?" discussing the lack of trained post-graduates for the workforce [23]. In 2000 Camp observed the surveys "show a small increase in the number

of women receiving B.S. degrees in computer science. However, they also show a steady decrease in the percentages of women receiving B.S. degrees in computer science" [15].

Reinforcing this view, according to data from the U.S. Department of Education and the National Center for Education Statistics as recently as 2005, the total bachelors degrees awarded in computer science has only gone up steadily from the mid-nineties to about 58000 in 2004, nearly 40000 more than electrical and mechanical engineering each.

Figure 1 – [14] →



←Figure 2 - [6]

Interpretation of these statistics also depends on the source of the data. If the data is focused on bachelor's degrees, separate consideration should be made for studies citing declared freshman majors and transfer students. Other studies, like those in Talking about Leaving, focus primarily on retention rates, rather than graduation rates [25]. Retention rates imply continuity from declared freshman majors to the culmination of a bachelor's award. This thesis focuses primarily on bachelor award rates because they provide the most recent

information as well as a better perspective on students entering the workforce, rather than students who may decide to switch majors after declaring CS.

The Engineering Workforce Commission database also provides information on demographics, as well as degrees awarded for various engineering disciplines [12]. In 2004, the national total number of degrees awarded in computing in the United States of America was about 64,000. As such, even with the discrepancies in classification discussed earlier, that number is comparable to the National Center for Education Statistics chart in figure 2.

Although the numbers seem to be in conflict due to differing information gathering practices, the sources of the information, and the disparate interpretations of the information, the end result indicates that United States undergraduates are continuing to show interest in the computer science field, though interest from the female side of the population is not increasing at the same rate as male interest.

The dearth of females, and of students that can be classified as other than white and male, is a concern for several reasons. Women make up about half the population of the United States. The talent and intelligence latent within the female population goes untapped if females do not participate in all workforce and educational endeavors. Along this train of thought, several books have been written citing that women have different areas of natural talent that would benefit a field dominated by only one type of philosophy [12].

In *A Strategic Plan for Excellence* put forth in 2003 by the University Of Colorado College Of Engineering and Applied Science the report cites one of Engineering's goals as to "Increase diversity of our student population… with a 10-year goal of reflecting representation of women and minorities in our region" [13]. At the time

of the report, there were 18% undergraduate women in Engineering, which was roughly the national average at the time. In 2004, the number was about the same, 17% total undergraduate women in the Engineering center, according to Engineering Workforce Commission data. However, there were only 8.7% women in the undergraduate ranks in computer science in the same year, lagging behind all other Engineering departments. The national computer science numbers are similar, with 12% undergraduate computing women.

In spring 2007, according to the public data provided by the University [14], 21% of the current population of undergraduate engineering students are women. This improvement, of three percent in four years, may not be reaching the stated goal. To reach the goal, however, the population of females within computer science must reach the regional average of roughly 50%. With about 10 female students and over 200 students in computer science as undergraduates, female CS population hovers below 5%.

These numbers stand to be improved, and the computer science department expresses a desire to see the percentages rise. However, because of the lack of student female presence within computer science, any steps taken to affect gender-related issues among undergraduates have a very limited audience. In order to affect the entire undergraduate population, there are several solutions to problems identified as 'female' that can be applied universally to both genders to improve the quality of teaching and curriculum.

Part II: Toy versus Tool

The focus of curriculum is one of the accepted reasons for why women are not participating as heavily in computer science as men. More precisely, depending on whether the coursework is focused on the 'toy' or the 'tool' aspect of computer science, women will be more or less inclined to participate in academic programs.

'Toy' refers to the male tendency – based on research by Jane Margolis, Allan Fisher and Faye Miller from Carnegie Mellon [20] – to be more involved with the tinkering, building aspect of computers. Computers are treated as toys to experiment with, play with, and develop 'cool stuff' with. On the other side of the gender gap, females tend to want to deal with the 'tool' side of technology. This refers to the desire to create something functional and focused for cause, a project, or a community need. The 'tool' would provide the student a service of some sort.

It is because of this idea that programs such as 'Technology for Community' established in 2001 at the University of Colorado Boulder try to attract women into technologically-focused majors with a tool-oriented approach [18]. The study showed a higher proportion of enrolled female students than other computer science courses. However, the program met with limited success since it did not encourage females to go into the more traditional computer science major.

This straightforward idea, to attract women to computer science by changing focus of the curriculum, is not without exception and the women who enter into current computer science programs and earn their bachelor's degrees arguably are the type that can and will excel without extra focus. However, the idea that women are the only

students that care about social relevance outside of the classroom is, at least a CU, a myth according to survey comments. [See Appendix A for further discussion of survey interpretation.]

Male student comments from the University of Colorado's graduate survey in 2006 illustrate that while male students who stereotypically enter the computer science program might be focused on the tinkering aspects of computers and computing, there are more that "…would like to see classes that discussed other aspects of computing. Most of these include newer/advanced technology and web based ideas" [26].

While the Alliance for Technology, Learning and Society (ATLAS) on campus attempts to provide 'bleeding edge' classes for advancing exploration into web-based technology, computer science has room to implement similar - more programming and theory oriented and less art oriented - classes that delve into areas of advanced technology.

A CU student – male, as there were few female respondents – from the same survey also commented that "I would prefer this material were folded into a larger-context class with more engaging projects which demonstrate the usefulness of the tools." More often than not, students cited the class Senior Projects as the most beneficial class they took in the computer science program at CU because it drew together all of the theory and the programming practices learned throughout the previous three to five years.

This desire for relevance, expressed recently within the senior exit survey, has already been addressed by the CS department at the University of Colorado by the provision of a one credit hour course that gives CS majors an overview of possible

applications of their chosen major. Many students in the senior exit surveys thought it was a wonderful class that illustrated the myriad of occupations waiting for a computer science major after graduation. Of the roughly forty respondents there were four that expressed satisfaction with the class as opposed to the one that called it an "… easy way to make a credit hour for nothing. Not needed."

The idea that 'extra' pampering of females is not necessary and the proposition that the computer science community operates as a psychological group are two concepts not often connected. The paper *Diversity - Not a New Idea: Group Dynamics and Resistance to Diversity in Engineering* explores the concept that the established group – here, white computer science males – resists the intrusion of *any* minority group because of the threat of punitive action. Imposing strictures to encourage female and minority presence at the expense of the existing community by authority figures creates a pre-existing negative atmosphere for incoming students be their gender, economic station or 'race', different [11]. The reaction against shifting to a design based, community based, or otherwise not-as-traditional course could be attributed to the same group reaction to newcomers.

Margolis and Fisher detailed the research and the curriculum changes put into effect to develop a more 'female friendly' approach to computing. Through explorations into the shifting of curriculum to cover topics that not only had more impact on the world, but sent out educational tendrils into other areas of study proving that the discipline was not taught in a theoretical void, Carnegie Mellon increased their female enrollment over five years from just under 10 % to nearly 40%. All without, as some complain will happen when the curriculum gets away from math and constant code

manipulations, letting the programming training suffer or neglecting the more traditional topics in computer science.

The good news is that the University of Colorado is already addressing part of the 'interest' issue by diversifying curriculum through a track program (called threads) that allows students to follow more individualized courses through the university system in different fields such as Software Engineering.

Part III: The Future

The concept of the pipeline is a flexible one, but the implied definition is the track that a college student takes from high school, to undergraduate through PhD and into industry within computer science [5]. The idea can also be extended back to the math and science courses in primary and secondary school, thus including them within talks of changing the culture of computing. Andrea Jepson and Teri Perl discuss outreach in high school and the reasons that children within lower-division programs do not continue to upper-division computer science [17].

Beyond the aforementioned disinterest in learning material, one cause of leakage can be attributed to the perceived lack of preparation for future positions within the workforce. The perception of difficulty in procuring a career after graduation has a negative affect on retaining women in computer science. Where there are no jobs available for women, due to sexism or preparation issues, then women will not pursue a computer science degree.

In the article *Caring about Connections*, by Jane Margolis, Allan Fisher, and Faye Miller [3], the authors explore female computer science interviewee opinions about how connection with the outside world – as above – is one of the primary reasons they go into computer science. Women in their survey respond by connecting what they are attempting to accomplish now with what they hope to be doing in the future. The male students do the same, but connect the product they will produce, not the occupation they will go into.

At Carnegie Mellon the computer science program implemented an 'immigration course' to assist in developing a broader view of where computer science fits within the

framework of research, development and the rest of the world. This approach, an overview type class with programming factoring as part of a whole, left students better able to answer the question 'What is computer science?' [19].

The relation between the CS major and the students' futures can also be attributed not just to a career choice but also to altruism and the desire to 'make a difference' [25]. Within the survey done between 1990 and 1995, 90.9 % of women and students of color expressed a desire to perform an act of service for the world as part of their choice for a science, math, or engineering field. Male students expressed a similar wish to pursue a career goal. The future of computer science is what draws some students into the major.

This future, though, is not always particularly clear for undergraduates. In a survey of four sets of undergraduates from Britain, Hong Kong, the United States and Australia, students were unlikely to categorize working in factories, hospitals, newspapers, or any company that uses a network as being part of their future computing professional career [8]. Even though students might wish to pursue an altruistic career, or simply have something they wish to do in mind, not many consider fields in the maintenance and construction of programs for companies not considered immediately as computer science.

In the graduation surveys [26], several students at the college were concerned about their future. A male student said that the major was "...not suited for the student looking to learn to program … classes were extremely theoretical, with very little coding..." while a female commented, "not a good start for someone wanting to go to graduate school and it is a poor general education for someone entering industry." In the 2005 survey another female commented, "I think more of the classes should be geared

towards helping us succeed in the industry. It seems like … professors … don't really form the class towards our future in the industry but rather our future in academia."

In the previous discussion, students expressed desires to enter into the workforce, but the University of Colorado is giving some students the perception that they did not get the experience they required. Fortunately, an equal number of surveyed students that commented that their Senior Projects courses, among other courses like Computer as Components and Linux Administration, more than adequately prepared them for the jobs they envision themselves performing in the future.

Part IV: Community Assistance

Alongside preparation for industry or another career path is the delicate matter of mentors, learning assistance, role models, and other supportive action on the part of the university. Research indicates that female students are more confident and perform better if they have access to these types of assistance. Research shows how young women can become more engaged when they realize that computer science and the related technological fields are not just "sitting in a cubicle, programming" [17].

Studies, like one performed by the Association for Women in Science (AWS) [2], illustrate that having active role models in the faculty and industry becoming successful with families and children gives rise to nearly 70% retention of women within science fields. There are practical guides to establishing mentors in science and engineering departments with guidelines that emphasize the time commitment and the personal and interpersonal interactions with the mentor and mentee [27]. Additionally, it also illustrates that larger groups of students with one mentor can also be equally beneficial by establishing an artificial identification group to assist with homework, classes, and other forms of support. An artificial identification group is a collection of individuals gathered by some arbitrary means and required to respond to each others questions with assistance.

The University of Colorado is one of many universities to be home to a program which assists in the mentoring of science, math, and engineering students. CU has the Women in Engineering Program, also known as WIEP, which provides a space for women, knowledgeable faculty, and opportunities to interact with the engineering community [4].

Unfortunately for the University, only one computer science female participates with the program or utilizes the facilities. Established this year, however, there is now a Women In Computer Science (WICS) program slowly gathering speed to encourage open-option and waffling majors to continue with computer science.

Mentoring and extracurricular assistance seems to be one of the points on which computer science at the University of Colorado leaves a few students unsatisfied. In comments from male students in 2005, and 2006 [26] a student said that: “Unless someone is a very self-motivated student, they will not exceed at CU. The professor[s] here do little to draw out students.” Another student commented, “I didn't feel that there was adequate support or guidance from instructors and professors.”

These comments from graduating seniors from computer science illustrate the need for more than just female students to have the mentoring and assistance required to succeed.

Part V: Isolationism and Competitiveness.

Mentoring and the related classroom assistance is part of another facet of 'female-friendly computing' that applies to the male students here at the University of Colorado. In 2000 to 2002, a study done by Attracting and Retaining Women in IT (ARW) investigated the classroom atmosphere at the University of Colorado within introductory computer science courses. Through observation and survey responses the study discovered that there were several practices put in place by the teacher of the class – without consciously realizing it – that made the classroom a less cooperative, inclusive space. The term 'isolationist' is used, meaning that students would feel less like they could ask for help and that their failing at assignments were the fault of stupidity rather than lack of assistance. Also applied to the observed environment was the term 'competitive' [3].

Female and male educational advancement suffers in these types of classrooms. When personal achievement, even over the teacher, is celebrated as part of the competition, organizations beyond college have reason to worry that students will not be able to function in groups [7]. The sense of community that could needs to be fostered in the classroom directly impacts the quality of 'group work' developed by students.

Beyond working together rather than competing with each other, the teachers themselves acted in the study as a focus for which questions may or may not be answered, cutting the rest of the class out of the learning experience.

Part of this isolationist classroom can be attributed to the students themselves. The personalities of the students develop an isolationist and competitive classroom based on the culture they bring with them.

In responses from two male students from the graduate surveys in 2005 and 2006, this atmosphere, and attitude, is reflected in the following quotes [26]:

"… there is often a lack of a feeling of community among the college and computer science particularly."

"I always felt like I was competing with my peers. Granted, part of earning grades in a university environment necessitates competition - I just felt that the competition to excel over my peers with more experience was overwhelming at times."

Male students clearly respond to the competitive atmosphere and the University of Colorado Honor Code adds another layer of confusion to the whole concept of a cooperative classroom. The code states:

"On my honor as a University of Colorado at Boulder student, I have not given nor received any unauthorized assistance on this work."

Computer science, as a field that requires working in groups and researching code from other sources, takes an ambivalent stance on the honor code. This ambiguity with respect to who authors the class work or where code, algorithms, and theory is found leave students and teachers trying to decide if asking a neighbor for help debugging or which snippet of code works best violates the spirit of the honor code. When the default answer is yes, the student then isolates himself or herself for fear of repercussions.

The dearth of programming confidence that causes first-year computer science students to leave is *part* of the culture and is based upon the idea that the more programming skill and experience the student enters the program with, the more intelligent the student is. Carnegie Mellon University successfully implemented separate programming tracks to give various levels of experience and challenge to level the playing field to combat this problem. The stereotype of a 'Boy Genius' hacker lurking in a basement with a green-glowing computer screen, toppling the world from the inside of the Internet is the stereotype that new students compare themselves to when completing programming assignments [19]. If the program is not as 'easy' as the teacher, TA or even their own imaginations require it to be, the student believes they are a failure in the field.

As an example of this concept of Boy Genius and how experience is necessary to participate in the current program, another male student from the 2006 graduating survey commented that the CSEN program was "not a program someone with limited experience before college can succeed in without a large amount of hardship."

Conclusion:

Women, as discussed here, are not leaving computer science in large quantities, but not entering computer science at the same rate as male students. There are several reasons for this nationally. First, women are – while not disinterested – less inclined to feel as if the curriculum is suited for their needs. Second, women are less inclined to feel that a computer science education will allow them the high-paying jobs, altruistic opportunities, or educational futures allowed their male counterparts. Third, women do not feel they are getting the assistance within the field required to excel. Last, women buy into the stereotype of what computer science is supposed to be and judge the entire field from the narrow view presented by the media, their peers, and their teachers.

At the University of Colorado, the needs of the students are very similar. The low concentration of women does not mean that the department escapes many of these issues. At the University, both male and female students express a desire to learn more about their chosen, sometimes cutting edge, fields. Second, some students express a desire to see more preparation for the workforce, rather than for academia. Third, several students expressed the worry that they had a disproportionately difficult academic career because of lack of resources. Last, both male and female students buy into the stereotype that characterizes computer science.

However, there were several female issues that I found no evidence of, or at least very little, at the University of Colorado. One of these was gender bias and the sometimes insinuated belief that women have no place within the technical workforce. Luckily, I found only anecdotal evidence to support any claim of bias at CU. Another issues I found little evidence for was any type of outreach. I suspect that this is because the majority of college students are not inclined to pursue outreach programs upon graduation.

One issue I'm pleased to report does *not* seem to be present at the University of Colorado is a lack of female faculty. With a faculty that possesses a robust percentage of women, the University is not in immediate danger of losing women because of the lack of role models in the community.

The University Of Colorado Department Of Computer Science, however, stands to improve the curriculum in a number of ways. Fortunately, measures are already in process that will help relieve some of the problems discussed by students. One previously mentioned, is being implemented by the thread system.

To address other issues, implementing a more holistic approach to teaching at the University of Colorado would greatly benefit both male and female students. This approach would eliminate the classroom atmosphere at the undergraduate levels and allow for greater diversification among the students. Additionally, the approach would help abolish some of the computer science stereotypes, attracting not only women but male students whose personality types are not traditionally considered.

Building a community among the undergraduates – all the undergraduates – would also benefit computer science. Currently – as a fellow student remarked "What community?" – there is no sense of being able to go to fellow computer scientists and ask for help, or be able to spend leisure time together unless the students managed to meet somehow out of classes. This area, too, could stand to be improved.

Computer science at CU is on its way there, and while the numbers suggest that the department could use a few more females, there is an aspect of hope for future gender equity. To begin, though, these few issues and their solutions could make the University of Colorado a more accessible institution for both male and female students.

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Appendix A: Student Senior Survey

The University of Colorado senior survey, from which this thesis garners many of its direct quotes, is a voluntary survey submitted online. The response rate was roughly 30% both the year 2006 and 2007. The survey consists of a few general questions about the university, questions about the College of Engineering, and a section on questions specifically geared towards CSEN majors.

The majority of the survey questions were of the format 'rate from 1 to 5' or a similar radio-button selection format. As an example:

Please rate from 1-5 –

- How well did your college prerequisites prepare you for computer science courses?
- Did computer science provide a supportive learning environment?

The majority of quotes came from questions formatted like "What were the highlights of your experience at the University of Colorado? What were the worst parts?" Additionally, the survey queried, "Would you recommend the University to a friend? Would you recommend Engineering? Would you recommend your major?" each followed with "Why or why not?"

The free response sections for Computer Science consisted of, "What were the most educational experiences? The least educational experiences? What were the deficiencies of the program and what would you suggest as improvements?"

The survey, being voluntary, asked for each students most concerning opinion. Although the response rate for the survey was relatively low, the significance of the comments is bolstered because they arrived with little prompting on the part of the survey.

Appendix B: Possible New Survey Questions

The senior survey, as a tool, could be adapted to further investigate several of the ideas discussed within this thesis. Some example questions for exploration could be:

- How did the Honor Code affect your CSEN classroom experience?
- What project provided your most valuable learning experience?
- Did you witness other students being treated differently due to gender or minority status?
- Did you have a mentor?
- What was your most positive group-work experience? Most negative?
- As a follow up questions to 'Rate your Experience with Senior Project:"
  - How did this course affect your opinion of CSEN?
  - Would you have placed this course earlier in the CS curriculum?

Information that would be incredibly valuable if the senior survey were filled out in large enough quantities would be the open option data. There's a current question that asks if the student started open-option. Expanding on this would be a question of what major they started as or transferred through. Transfers in and out of the major are hard to track the information could be valuable. Also, even a little bit of encouragement to answer some of the already established questions would benefit the research community.

One section of the survey that would also be very valuable if more students responded to it would be the other programs asked about only in radio buttons. As the survey is set up, sometimes a survey choice will activate another part of the questionnaire. Expanding this to include Space Grant, the WIEP with respect to computer science would garner interesting comments.