Recruiting Women into Computer Science and Information Systems

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Abstract

While many technical disciplines have reached or are moving toward gender parity in the number of bachelors degrees in those fields, the percentage of women graduating in computer science remains stubbornly low. Many recent efforts to address this situation have focused on retention of undergraduate majors or graduate students, recruiting undergraduate women into graduate programs, or appealing to girls through K12-focused experiences. Our approach focuses more specifically on recruiting women to take their first "major-track" computer science course (CS1) and strategically redeveloping that course to spur interest in computing. Our strategy for so doing is to better understand how women view computer science prior to any direct experience in college-level study, developing a woman-centered first programming course that focuses on fundamentally-sound curriculum, addressing the retention recommendations offered in other studies, and face-to-face recruiting to encourage students to register for their first course.

Introduction

In 2010, only 18% of computer science bachelor's degrees were awarded to women, despite the fact that 37% of such degrees were awarded to women in 1985. [1] This worrisome trend was noted by many computer scientists and was systematically studied in an attempt to reverse it. The Computing Research Association's Committee on the Status of Women in Computing Research produced a report aimed at summarizing much of this work. This report presented a list of 20 recommendations for recruitment and retention of women in graduate computer science programs. It also presented many findings intended to help guide the understanding of college and university educators as to some general - although not universal - factors in how, when, and why women become interested in computing.

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> "Men are more likely than women to become interested in computing at an early age—often describing "epiphany moments" that occurred even before the age of 10—and they are more likely to be interested in computing for its own sake, whereas women tend to become interested in CS as an "acquired taste" that emerges over time. Frequently, women are interested in computing for its potential applications to societal concerns or other areas of interest such as education, medicine, art, and music. As a result, they may come to computing at a later stage in their education, perhaps after having majored in some other discipline." [2]

There are many possible reasons that women students nationwide do not complete a program of study in computer science. Many of the reasons that appear in the literature pertain to social dynamics between men and women or the need to mitigate cultural norms in computer science and information systems that are not particularly friendly to women. Indeed, of the recommendations of the Status of Women in Computing Research report, about half of the recommendations were specifically aimed at dealing with such issues.[3] Understanding why women do not complete programs in computing is certainly of great importance. This approach improves the percentage of women who complete a major, assuming that they began the major.

It is important to note that the women considered above eventually expressed a strong interest in computing by majoring in it or deciding to study it at the graduate level. Many others with the necessary skills and ability do not take this step. Indeed, although it is not entirely clear why it is so, it is certainly true that many skilled and capable college and university students - men and women - never take a single course in computer science or information systems.

The approach of this study is to improve the number of students who begin to study computing. Keeping in mind lessons learned in the literature, we focus on four specific areas: students self-evaluation of their attitudes toward and preparedness for studying computer science, the development of a woman-centered introductory course, addressing the retention recommendations provided by the literature, and face-to-face recruiting.

Attitudes and Preparedness

Many studies have focused on how to improve the attitudes and preparedness of K-12 aged girls with respect to computer science (and STEM studies in general). This area of study (and the outreach that often accompanies it) is crucially important, given that students generally have less formal experience with computing in the K-12 curriculum than they do in many other fields. Moreover, girls and young women make up a proportionately small number of computing students. Indeed, among Computer Science Advanced Placement test takers, only 18.7% (5,807 out of 31,117) were women in 2013. [3] Meanwhile, roughly 178,000 women took the the Calculus AB or BC AP exams. [3]

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3 Of the 20 recommendations in the report, recommendations 9, 10, 12, 13, 14, and 19 pertained to social dynamics while 7, 11, 15, 16, 17, and 20 pertained to cultural norms. [2]

This suggests that most institutions have many students capable of studying computer science who - for whatever reason - have not done so. For example, at Saint Mary's College we typically have approximately 150 women studying at least one calculus course each year[4], but typically only 35 to 50 women per year study computer programming[5]. Certainly there are many more skilled and able women aside from those who take our calculus courses, but there are also many calculus students who never take CS1.[6] Other talented and interested students who are not studying Calculus simply add weight to this argument.

To understand how to address these students, we developed a short survey[7] to investigate women students' attitudes toward studying computing. This will be called the Attitudes Survey for brevity. The survey instrument was administered on paper and in person to students in randomly - but representatively - selected course sections in mathematics at Saint Mary's College during Fall 2013. All such courses were general education courses aimed at first year students. All students participating in the survey were women. No identifying information was recorded. The survey was aimed at understanding the degree to which students are comfortable with common technologies in an academic setting (comfort), interested in computing and computing devices (interest), and aware of the applications of computing to their areas of academic interest (relevance). The survey also investigates how students perceive the difficulty of scheduling a programming course into their schedules (logistics). The survey then investigated how students perceive careers in computing. A total of 112 students responded to this survey.

4 This is the average yearly enrollment in our entry Calculus courses over the past six years. Some students enter directly into Calculus II or above, and are not included. Data obtained from our Banner student information system.

5 This is the average yearly enrollment in our CS1 course combined with the average yearly enrollment in our engineering program which is hosted at the University of Notre Dame. The Intro to Engineering course counts in replacement of the CS1 course for certain major requirements at Saint Mary's.

6 Students at Saint Mary's are generally given a math registration recommendation based on the results of high school math grade, entrance tests (SAT/ACT) and a placement examination. Generally speaking, these calculus courses are populated with students who are well-prepared for calculus.

7 This survey instrument was approved for research purposes by Saint Mary's College Institutional Review Board in October 2013.

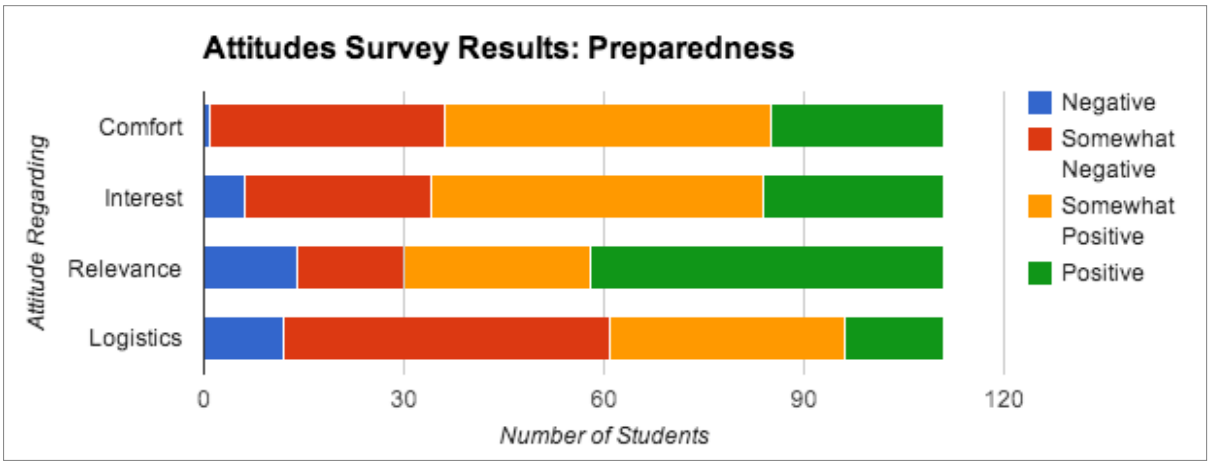

Figure 1: Attitudes Survey Results regarding student preparedness to study computing

The results of this survey pertaining to the first four "attitudes" (comfort, interest, relevance, and logistics) are displayed in Figure 1. It is clear that these women widely regard computing as relevant to their career choices, since 81 out of 112 (72.3%) rate the relevance of computing in their field of study as at least somewhat positive. At the same time, fewer than half (50 out of 112) are even mildly optimistic about the logistics of actually taking our CS1 course. Those who respond negatively on this item were primarily concerned about needing to significantly rebalance their academic workload (49 out of 61), although some (12 out of 61) feel that their grades would suffer. The results for comfort and interest level appear similar. In each case, about two-thirds of students reply at least somewhat positively, 67.6% and 69.3% respectively. This will be investigated in somewhat greater detail in the discussion of Figure 3. Overall, the results of Figure 1 seem encouraging.

The Attitudes Survey also addresses the question of how students perceive careers in computing. Figure 2 presents these results. The percentage of positive responses ranges from a high of 69% for Social Impact to a low of 57% for Dynamic (meaning whether or not such careers are dynamic and interesting). We note especially that 68% of respondents believe that careers in computing are Good for Women which seems positive, but which also suggests that 32% of respondents currently feel that careers in computing are not good for women, suggesting that the "burden of proof" is still on the technology sector to demonstrate otherwise. Moreover, although careers involving computing are among the most lucrative in the United States for college graduates and regularly feature in popular media about top careers for college graduates, students are less aware of this than they are of many other aspects of careers in computing. On the other hand, many of the clichés that are popularly ascribed to technology workers, such as that they are detached from "real life," only for geeks, or that they work in isolation do not seem to be as firmly entrenched as one might fear. The most curious of these perceptions is the one titled "Normal" which asks students if a career in computing is "compatible with a normal life." There certainly is no canonical interpretation of what a normal life is. Students may be responding to another cliché about technology workers, namely that they are always working. It is hard to tell for certain what this particular number means, except by interpreting it as an feeling of personal relatability. It does not deviate much from the other six perception scores, but it may "take their temperature." Overall, the results of Figure 2 seem encouraging.

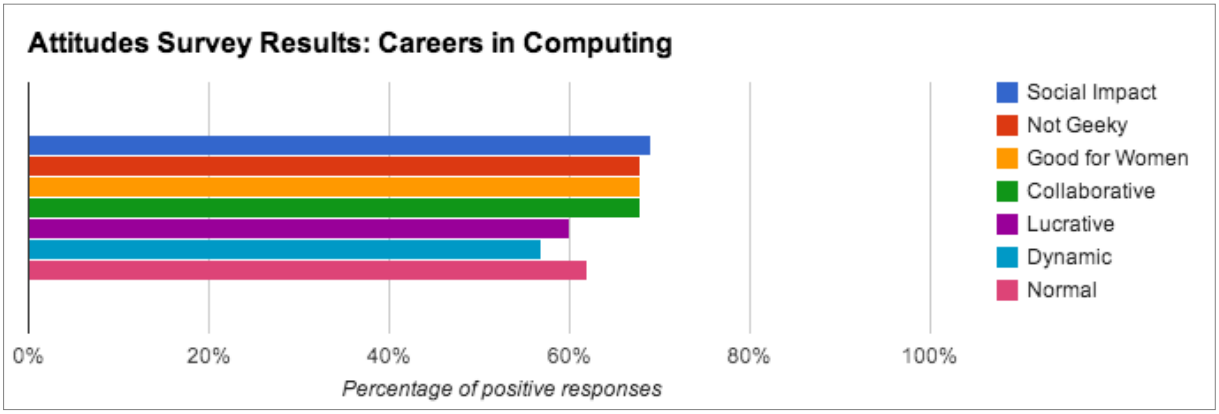

Figure 2: Attitudes regarding careers in computing

The difficulty in understanding the results from Figures 1 and 2 is that while there may be some correlation between these variables (i.e., the various attitude scores), the relationship is somewhat loose. For instance, in the case of students' comfort level and interest in computing, it is certainly possible that a student might self-evaluate as very interested but not terribly comfortable with computing. One may suspect that these two aspects of "preparedness" to take a CS1 course may be the most influential in determining whether or not a student registers for the course in the first place. If she's either not comfortable with computing or not interested, it seems considerably less likely that she would actively seek to undertake the course without active mitigation of one or the other (or both) of these worries.

Figure 3 explores the interaction between these two variables. This figure demonstrates that a large proportion of students who are interested in computing (High or Medium for interest) are nervous about using it in an academic context or actively avoid it. It also demonstrates that many students who self-evaluate as Experienced or Confident technology users are not especially interested in discovering anything new within that sphere. Fewer than two-fifths (39.7%) of respondents rated themselves as both reasonably interested and comfortable with regard to computing. Add to that students' logistical concerns and it is easy to see how a well prepared, intellectually vigorous student might reach the end of her undergraduate career without ever taking a computer science course.

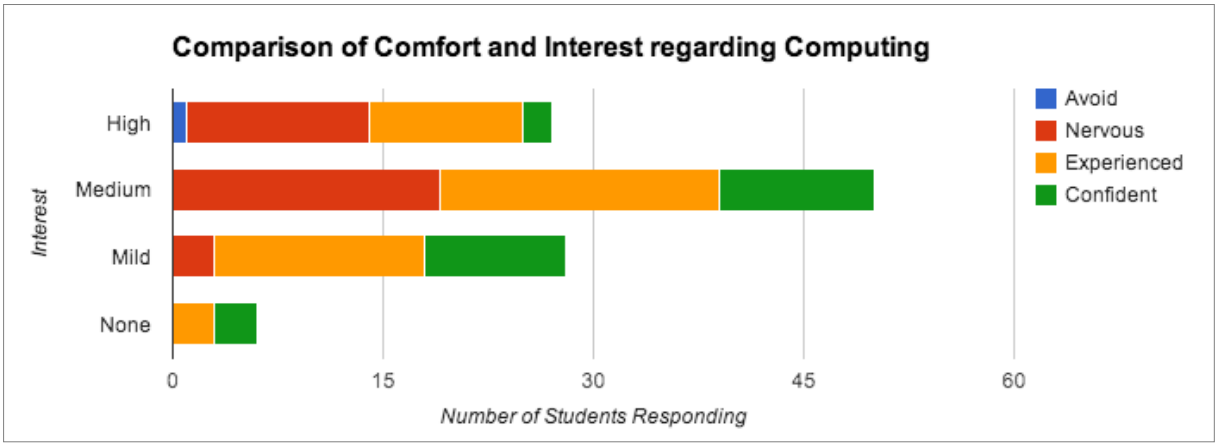

Figure 3: Attitudes Survey Results comparing student interest level and comfort level

Overall, we interpret the message of this data in the context of Saint Mary's College as offering opportunities and insights about how to improve the number of students taking CS1. In particular, we don't need to spend as much time worrying about whether or not students think computing is a relevant skill. Instead, we need to develop and market a course that leverages the perceived relevance of computing, emphasizes the power of computing in combination with other technologies to improve students' interest, and provides an inclusive, welcoming, and nurturing environment in which to gain access to critically important ideas and skills.

A Woman-centered Course

Issues pertaining to social dynamics and woman-unfriendly cultural norms are less immediate at Saint Mary's College because we are a women's College. This gives us an opportunity to develop, implement and conduct an entirely woman-centered computer science and information systems curriculum. This should - in principle - remedy many of the issues related to cultural norms that arise in programs nationwide. Additionally, at Saint Mary's it is almost exclusively[8] women students who define the social dynamics and cultural norms in the classroom. Certainly, a male professor might have a significant impact on those dynamics and norms, but faculty are certainly encouraged to be open to their students' needs and preferences.

Supposing that such cultural issues were fully resolved, one inevitably arrives at the following questions: "Is that enough? Can we now continue doing what we have always done?" These questions are a bit disingenuous in the sense that it would be very difficult to fully disentangle the curriculum from the institutional culture. However, we assert that it is difficult to address these cultural issues without first addressing the curriculum and that beginning an iterative process of curricular revision may be a necessary precondition for cultural transformation.

Curricular revision should proceed in such a way as to reduce those factors that are perceived to discourage women in computing and improve those factors that encourage women and promote retention in computing majors. We present a collection of observations and suggestions from the literature pertinent to those factors. We group them into several categories: dispositional, institutional, cultural, and pedagogical, recognizing that some of these could reasonably fall into more than one category. In the discussion that follows, the text will refer to these observations by number e.g., Obs 1 meaning Observation 1 in this list.

The dispositional factors are those that relate to a woman student's general point of view. An individual woman may relate to all, some, or none of these, but the literature identifies them as being more often associated with women students than men.

1. "Women, even though they perform at the same levels, have less confidence in their abilities and individual accomplishments than men." [2]
2. "Women are often less aggressive than male students in promoting themselves, attempting new or challenging activities, and pursuing awards or fellowships." [2]

8 Occasionally, men from other nearby institutions take our CS1 course.

3. "Females come to computing as only one interest among many." [2]
4. Women are often "less single-minded than their male counterparts." [2]
5. "Women are interested in computing for its potential applications to societal concerns." [2]
6. Women have "other areas of interest such as education, medicine, art, and music." [2]
7. Women "may be more sensitive than men to social feedback." [2]
8. Women may be "more responsive to encouragement, personal recognition, and individual invitations from faculty." [2]
9. Women often report struggling with "'impostor syndrome,' an internalized feeling that women simply don't belong in tech." [5] (This factor, in particular, belongs in multiple categories.)

The cultural factors are those pertaining to the overarching culture of computing and the societal expectations of those professionals and academics associated with computing. These are values that students may be acquainted with through pre-college experiences.

10. Computing is a "male-dominated, hacker culture." [2]
11. Women "may come to computing at a later stage in their education." [2]
12. Women are "more likely to interrupt their education for family reasons." [2]
13. Women benefit from knowing that "many different kinds of careers that can be launched from this education." [2]
14. "The culture that develops around computer science departments is often unattractive to women." [4]
15. "When girls think of computer science, they think of the gamers and sitting in a cubicle to program." [1]

Institutional factors pertain mostly to attitudes, actions, and initiatives that institutions can take at the program level to make computer science and information systems amenable to a greater diversity of students.

16. "Department literature and departmental visitors [should] include women whose lives and careers do not reinforce the standard clichés." [2]
17. Focus on "increasing the number of women enrolled in computer science, [not] the percentage." [4]
18. "Develop a community of women in computer science." [5]
19. Offer "early exposure to research projects during the first year of college." [1]
20. Offer "opportunities for undergraduates to interact with women who have enjoyed successful careers in technology." [1]
21. "Facilitate mentoring." [2, 6]
22. "Make timetables flexible." [6]
23. "Arrange for [current] women ... students to meet with prospective women students." [6]
24. "Incorporate research into the standard undergraduate curriculum." [2]

Pedagogical factors are those that can be addressed in individual courses to improve the likelihood that each individual woman will view computing coursework as a good fit for her aspirations.

25. Emphasize the "professional contributions of women ... in classrooms and lectures." [2]
26. "Support the formation of short-term peer support groups, for example, for cooperative classroom activities." [2]
27. Make the introductory courses "accessible to a much wider audience." [4]

28. "The level of [pre-college] computing experience ... differs markedly with gender." [4]
29. "The course is designed to encourage all students rather than to select the best." [4]
30. "Women bring a different perspective to solving problems." [5]
31. Cultivate "a classroom atmosphere where passing judgment is avoided, all questions are treated with respect, students' ideas and thoughts are explored, and learning is collaborative." [7]
32. Incorporate "more-diverse programming activities" to appeal to a range of students. [1]

Our approach to the development of a woman-centered CS1 course incorporates responses to many of these observations. In particular, the CS1 course at Saint Mary's College is a part of the general education curriculum, assumes no prior computing experience, provides a supportive environment for active, collaborative learning in lab experiences, emphasizes personalization of projects, values clarity over brevity in code writing, and emphasizes the applicability and power of computing by leveraging web services. A CS1 course with this construction directly addresses all of the pedagogical factors listed above at least in part, and indirectly addresses many of the dispositional, cultural, and institutional factors as well.

Include CS1 in General Education

The general education program at Saint Mary's has recently (2012) been restructured in such a way that CS1 can be part of the general education curriculum. When it comes to recruiting students, courses that participate in general education have a clear advantage. Indeed, considering the logistical difficulty noted above, this could be construed as addressing the accessibility of the course by allowing it to satisfy requirements in the general education rather than just as elective credit, thus reducing logistical barriers (Obs 27). The curriculum of the course was revised somewhat to include some discussion of the ethics of computing and a modest writing component (Obs 31). The curriculum revisions necessary to add the course to the general education curriculum also required the course to have relatively little presumed background knowledge (Obs 28). A position in the general education curriculum also arguably sends a different message to students about the nature of the course, namely that it is a course for everyone not just a special category of people (Obs 27, 29). We feel that offering CS1 as part of the general education curriculum makes sense, aligns with the needs of men and women students, and makes a positive contribution to the character of the course.

Do not assume any prior experience

First courses in computer programming almost never require prerequisite courses. This would suggest that students with no background should not feel at a competitive disadvantage. Women do, however, report feeling relatively unprepared for the early coursework in some settings [e.g., 8]. At Saint Mary's, we actively frame computer programming as a novel undertaking (Obs 27, 28). There is no assumption of any particular mathematical background, familiarity with process diagramming, propositional logic, or any significant computing skills beyond web browsing and word processing. Students are actively informed of the absence of such assumptions and that the course is motivated by a desire to avoid competition and develop a framework in which all students can be successful (Obs 29). The CS1 course at Saint Mary's has a very low rate of students attrition (less than 5% over the past three years).

Develop a supportive and collaborative environment

Students in the first programming course at Saint Mary's are encouraged to work together in laboratory and homework assignments (Obs 26, 31). Students are actively encouraged to make their work unique and to add their own personal touches to their assignments (which also helps mitigate concerns that students will not do individual work individually). During lecture hours, students are often asked to begin the class with a group warm-up exercise. For example, when discussing inheritance students are asked to identify the similarities and differences between a collection of loosely related types of objects like animals or ice cream flavors. Students' responses are then used to motivate examples of class hierarchies (Obs 31). Each individual student typically makes contributions to such exercises, which means that rather than bringing a categorical woman's perspective to bear, the problem solving strategies of a diverse collection of individual women are on display with no need to generalize to the category of women (Obs 30). Past students who are working in computing fields are often invited to visit classes and present their own experiences (Obs 25). Students become very comfortable expressing their thoughts, concerns, questions, apprehensions, and so forth in an environment that invites ideas and values them.

Allow students to personalize projects

It is not uncommon for CS1 courses or programming courses in general to require the output of student programs to match some specific structure or interface. There are certainly good reasons to specify such requirements, such as ease of grading, simulating a commercial environment, or appreciating the rigidity of input/output transactions. At Saint Mary's, we choose a more student-driven strategy, although it is inefficient and does not scale well. Students work at the project level and develop their own understanding of the assignment whether in lab, homework sets, or formal programming assignments. This is meant to better value individual student's perspectives (Obs 30) and improve students' engagement in their programming projects (Obs 32). Very often students incorporate ideas or data from other areas of interest into their programming projects (Obs 5, 6, 32). This strategy seems successful at least anecdotally, as many students clearly remember the details of their projects after several semesters.

Emphasize clarity as well as (or in preference to) brevity

One cultural aspect of computer science that undermines the implementation of responses to Obs 27 through 31 is a pronounced preference for the most succinct code to accomplish a particular task (what one might call a brevity metric). In some cases, this preference for brevity is undermined by pure performance considerations. The brevity metric also encourages students to devise programming solutions that are not easily understood, which is not very helpful in a commercial environment since terse code is often easily broken. Most importantly in our context, it develops a culture of exclusivity (you get it or you don't) which is not open for interpretation (Obs 29). The course at Saint Mary's emphasizes a preference for clarity over brevity which is much more likely to allow the perspectives of individual students to be expressed and valued (Obs 31). This means that there are many "best" solutions, and thus students are more likely to feel their work is valuable.

Integrate web services into the introductory course

The great value of introducing web services in CS1 courses is to "make them more interesting and more importantly, make the students better prepared for upper division classes and for the industry

upon graduation" [9]. Motivated by the observation that women tend to be drawn to CS by its application to other interests (Obs 3, 5, 6), and moreover that implementing a diverse set of programming assignments is one of our goals (Obs 32), web services offer an excellent opportunity to introduce a rich data experience in introductory programming. The course has a web service Java library which allows students to program web services without the need to open web resources or parse XML or JSON responses. The library has packages that wrap Google's Geocoding and Directions APIs, Ziptastic API, National Oceanic and Atmospheric Administration's weather API, the US Census Bureau API, Rotten Tomatoes movie reviews API, Chicago Transit Authority API, Wolfram Alpha API, Wordnik API and the xISBN API. The course also uses the Twitter4J Twitter package. This provides many opportunities for students to build programs that realize their personal interests.

These strategies have wide-ranging anecdotal support. The next stage of this project is to measure the impact of these strategies both at Saint Mary's College and elsewhere. At present, the above is a summary of our approach which is heavily influenced by recommendations and best practices in the recruitment and retention of women in computer science.

Face-to-face Recruiting

Another important facet of our strategy for recruitment into the CS1 course is face-to-face recruiting sessions. Faculty from computer science conduct face-to-face recruiting in introductory mathematics courses. The faculty give a five-minute introduction to computer programming including some information about the range of careers impacted by computing, the general nature of the first course, some hypothetical examples of potential student projects, and an overview of the philosophy of the course and its goal of inclusiveness. Indeed, in Fall 2013, this recruiting talk was given immediately following the administration of the survey instrument described above. Students heard a five-minute talk explaining the learning outcomes of the CS1 course. This presentation could possibly be given via streaming video, but we recall that Obs 8 above indicates that the personal approach may be more effective in making the kind of connections that could overcome many of the negative impressions students may have of computing.

The small class sizes and collegiality of the faculty at Saint Mary's College make it possible to engage students at this level. A useful alternative to this strategy in a larger institution could include having advanced students in computer science or information systems visit small group recitations or tutoring sessions. In any case, the face-to-face interaction between "insiders" and students who have not yet had any computing experience is a critical piece of the strategy.

Conclusions and Future Directions

The core curriculum of CS1 contains many opportunities for addressing the needs and preferences of women and other diverse groups of students who are otherwise uninitiated in computer science and information systems. At Saint Mary's, we have discovered that our women students are generally well-disposed to toward computer science and careers in computing. However, many students are concerned about the logistics of actually taking that first course. To encourage women to begin, the computer science faculty at Saint Mary's have actively endeavoured to develop a woman-centered course which addresses many of the observations, recommendations, and best practices developed to recruit and

retain women in computer science. These passive measures are supplemented by active, face-to-face recruiting with possible students.

The next stage in this work is to explore attitudes toward computing at a range of institutions, among men and women, and to begin the process of measuring the impact of the steps we have taken to address the fit between a first course in computer science and the many women who may not yet imagine that computing can provide an interesting, satisfying and fulfilling career.

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