Mentoring computer science undergraduates

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Abstract

We investigated the nature and outcomes of faculty mentoring behaviour at 117 undergraduate computer science programs in the United States. Our data describe who mentors undergraduates, how much, in what way, and why. We also tested the relationship between mentoring and departmental outcomes including mean grade point average, retention in the major, progression to graduate school, and whether the gender balance of enrolment and retention are influenced. Our study found evidence that mentoring has a positive effect on how many of a department’s seniors go directly to graduate study and the quality of the programs these students will attend. It also appears that mentoring motivated by the desire for diversity helps retain women in computer science programs.

Keywords: mentoring, women in computer science, gender, grade point average, retention, attrition, progression to graduate school.

1 Introduction

Mentoring is frequently endorsed as an effective method for improving student outcomes. Despite some ambiguity about what effective mentoring entails in an academic setting and how implementation might affect outcomes, there are many who believe that active sponsorship by faculty is a positive force for student academic achievement and retention of under-represented student groups. Their faith has motivated countless individual faculty and departmental or school initiatives, plus several discipline-wide programs that attempt to provide women in computer science (CS) with the benefits of mentoring. For example, the Computing Research Association’s Committee on the Status of Women has run two NSF-funded mentoring programs for years. Support for these programs comes from industry, public and private foundation grants, and private donations. The promise and proliferation of these mentoring activities led us to
take a closer look at the nature and outcomes of mentoring in undergraduate computer science programs located in doctoral institutions. Our investigation is based on the assumption that departments where mentoring is a common practice should differ in measurable ways from departments where mentoring is rare.

2 Background

Belief in the value of mentoring is based on more than the many enthusiastic testimonials from participants in mentoring programs. Previous studies in other disciplines have found a variety of positive outcomes. For the most part, this research was conducted at single institutions and targeted only graduate students. The consensus of results indicated that certain mentoring activities were related to positive student outcomes ranging from increased satisfaction to increased productivity or retention in the program or institution. Studies disagree about the importance of matching mentor and protégé by sex, but it appears that this dispute arises from differences in the outcomes that were measured [1]. While it is true that students were more satisfied with same-sex mentors, it is also true that they experienced similar instrumental benefits regardless of their mentor’s sex.

An example of the general benefits of mentoring can be seen in one graduate-level single-university study that compared results for men, women, and women in male-dominated disciplines. Survey data obtained from more than 300 students over two points in time show that faculty mentoring increased protégé’s academic self-confidence and career commitment [2]. Mentor support was measured as a combination of both affective support, such as sensitivity to students’ non-academic commitments, and instrumental support, such as finding financial support. This comprehensive mentoring was positively associated with career commitment for both men and women, including women in male-dominated disciplines. Mentor support also had a particularly positive effect on the academic self-confidence of women in disciplines where the majority of faculty were men.

Another study demonstrated that mentoring of graduate students may have differential effects depending on the nature of the mentoring activities and the context in which they occur. For example, survey responses from almost 200 graduate students at a single university showed that instrumental mentoring had a significant positive effect on student publication records, but affective mentoring did not [3]. Students who reported that their mentors offered instrumental help such as improving writing and presentations, and exploring career options had more publications with their advisors than students whose advisors did not provide this sort of help. This effect held regardless of the discipline. (Nine disciplines were considered – psychology, economics, anthropology, history of consciousness, linguistics, chemistry, biology, earth sciences, and physics.)

Academic success associated with faculty mentoring has also been demonstrated at the undergraduate level. Mentored students in one university’s three year study earned .3 of a higher grade point higher average than non-mentored students who entered the study institution at the same time with the
same sex, ethnicity, and high school GPA [1]. Mentored students were also less likely than the comparison group to drop out of their institution.

Student outcomes specifically related to mentoring in the discipline of computer science have not yet been widely reported. Sturm and Moroh [4] included mentoring as one component in a multi-faceted approach to recruiting and retaining women in CS at a single institution. They produced a brochure, seminars, and workshops promoting women’s participation in CS, developed undergraduate research projects, and had women faculty teaching at least one section of every lower-level course, all in addition to a program of alumnae mentoring for undergraduate women. Unfortunately, it is not possible to discern what consequences can be attributed to women’s participation in the mentoring component of their efforts.

One publication indicates that mentoring may be related to women’s retention in undergraduate computer science programs. Departments where many faculty mentored their undergraduate students retained women at comparable rates to men, achieving an equality that is atypical in this discipline [5]. This statewide study of 23 CS departments suggested that faculty mentoring could help ameliorate the disproportionate loss of undergraduate women.

Our current report expands the statewide study of mentoring in computer science by examining one-third of the CS programs at doctoral-level institutions in the United States. We examine the prevalence and nature of mentoring in undergraduate computer science, and investigate the outcomes associated with mentoring of different types. Our findings show that faculty motivations and actions with respect to mentoring can have measurable department-level effects on students’ retention and progression in computer science.

3 Methods

We selected departments in Ph.D.-granting institutions that awarded thirty-five or more baccalaureate CS degrees in 1996 or 1997 (according to data available online at the National Science Foundation’s WebCASPAR), or that were among the 20 most prestigious computer science programs (according to the National Research Council’s 1993 rankings). As a group, these departments capture approximately one third of the USA’s computer science bachelor’s degrees awarded in recent years.

In spring of 2001, a survey of up to twenty-five faculty in each study department collected information on common mentoring practices, student grade point averages and attrition rates between 1994 and 2000. Participants were selected with a stratified random sample that over-selected female faculty. In most of the study departments, our selection method resulted in the inclusion of all full-time permanent faculty members who taught undergraduates. The overall response rate was 51% from an eligible sample of 1642 faculty members. Every department in the study is represented by at least one respondent, although some respondents chose not to answer all survey questions.

The questionnaire instructions define mentoring as “an out-of-class relationship that may be formal or informal. Office hours might include some
mentoring activities, but mentoring is distinct from academic advising. A mentoring relationship could include, but would not be limited to writing letters of recommendation. Mentoring entails activities such as: involving individual students in professional activities, offering personalized advice to individual students, encouraging individual students, and helping individual students establish careers”.

The survey questions relevant to this paper use a five-point scale to measure how often faculty engaged in seven mentoring activities. The scale ranges from never (1), to rarely (2), on occasion (3), often (4), and all the time (5). The mentoring activities were:

- Involve undergraduates in your research
- Publish research with undergraduates as co-authors
- Inform an undergraduate of research opportunities
- Supervise an undergraduate’s work that is not course related
- Help students navigate academic rules or requirements
- Encourage students who are shy but competent
- Personally give specific positive feedback to an undergraduate

Two distinct types of mentoring: research mentoring and support mentoring were identified from these different activities. Research mentoring is captured by the first four activities in the list – involving undergrads in research, publishing with undergraduates, informing undergrads of research opportunities, and supervising non-course work. Support mentoring is captured by the last three activities in the list that are more guidance-oriented – help navigating rules, encouraging shy students, giving positive feedback.

Additionally, respondents were asked to indicate whether they made a special effort to mentor particular students. If so, the survey requested that they indicate whether they mentored specific groups on a scale from not at all (1), to slightly (2), moderately (3), substantially (4), and completely (5). The options were:

- student eagerness to learn
- desire to overcome under-representation
- student need
- superior student ability
- personal rapport
- other (please list)

Responses to these survey questions were aggregated to the department level for analyses relating these data to outcome measures.

In order to measure outcomes, each participating institution was asked to provide data enumerating students by sex, academic level, grade point average (GPA), and outcome (persistence, switch to another major, etc.). These data proved particularly hard to come by. When the enrolment and outcome data were available, we used them to calculate rates of attrition from the major for each sex. The formula for the average departmental attrition rate was the six year average of students who switched to a different major, divided by that number plus the 6-year average of students who continued in CS each year. The gendered attrition rate was the male departmental rate minus the female departmental rate.
Thus, a value of zero or greater indicates that women leave the department at equal or lower rates than men, and a negative value indicates greater female attrition than male attrition.

We tested hypotheses predicting that departmental outcomes would vary by the type and amount of mentoring their faculty offered undergraduates. The outcomes we considered were student achievement measured by mean grade point average, rates of attrition to other majors, percent of seniors who progressed directly to graduate school, and the quality of the graduate program students to which students went. Based on the widespread endorsements of mentoring, we expected that more mentoring would be associated with higher GPA, lower attrition, and more students proceeding directly to graduate school, and entrance into higher quality graduate programs. We also expected that mentoring results would be particularly favourable for women students, and might even be associated with higher proportions of female enrolment. As you will see, the reality of outcomes related to mentoring is much less simple than our initial predictions.

Our methods introduced a couple of important limitations. First, in examining the link between mentoring activities and grade point average, our sample size is only thirty institutions. Sample size also meant that analyses including attrition or enrolment measures were limited to the 45 cases that supplied enrolment and disposition data, thus limiting the number of variables we could include at one time. Second, it is worth noting that our study is not necessarily applicable to other fields. Computer science departments provide a unique context that might or might not indicate whether mentoring activities or mentoring with certain goals in mind would produce similar results elsewhere. The findings of this study speak to computer science departments in doctoral institutions and can only be suggestive for other settings.

4 Results

Before reporting on the relationship between mentoring and student achievement, retention, and progression to graduate school, we describe who does what types of mentoring and how often. These descriptive results are based on CS faculty as a whole. They show that men and women faculty members at doctoral institutions are about equally likely to mentor undergraduates, but they sometimes engage in different types of mentoring for different reasons.

Faculty of both sexes mentored a median of 6 undergraduates in an academic year, and devoted a median of two hours per week to their mentoring activities. In most cases, the mentoring relationship was initiated by the student (62%). Occasionally mentoring was part of a formal program (less than 16%). The frequency with which mentoring involved particular activities is shown in Figure 1.

Several aspects of mentoring varied by faculty member sex (16% of faculty in our study were women). Women faculty were more likely than men faculty to engage in support mentoring activities. Women faculty were also more likely than men to initiate a mentoring relationship with an undergraduate student, as
shown in Figure 2. Forty-seven percent of men, but 63% of women faculty, made special effort to mentor particular students. Female faculty were more likely than male faculty to mentor female students, although all faculty members mentored more men than women. The latter fact is not surprising due to the gender composition of most CS programs. At 26% female, mentored students over-represent women, who comprised only 22% of the average doctoral program in our study.

Figure 1.

Gender Differences in Mentoring Behavior

Figure 2.

4.1 Motivation and mentoring

Faculty motivations for putting special effort into mentoring particular students are shown in Table 1. The data show that women were more likely than men to mentor because of student need and personal rapport, but the biggest gender difference in motivation is in diversity. Women were more likely than men to put
special effort into mentoring particular students because they wanted to overcome under-representation.

The way motivation was typically translated into action is measured by Gamma and shown in Table 2. Overall, these relationships were weak, but they showed some additional gender differences in faculty mentoring behaviour. For example, motivation by student eagerness was associated with mentoring for men, but not for women faculty. Thus, despite the fact that student eagerness was the strongest motivation leading women to mentor, we found nothing to predict what the nature of that mentoring would be. Likewise, despite being motivated by rapport, women faculty were not led to any particular mentoring action in response. Only in the case of diversity was women’s motivation translated into some of the specific actions we measured. When spurred to action by the desire to overcome under-representation, women informed and encouraged undergraduates. And women were significantly more likely than their male colleagues to take these actions under these conditions.

Table 1.

<table>
<thead>
<tr>
<th>Faculty Motivation to Mentor</th>
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<tr>
<td><strong>Eagerness</strong></td>
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<td>Mean</td>
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Table 2.

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<th>Significant Relationships between Faculty Motivation and Mentoring Activities</th>
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<tr>
<td><strong>Eagerness</strong></td>
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<tr>
<td>Involve</td>
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<td>.17**</td>
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<tr>
<td>Publish</td>
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<tr>
<td>-.22***</td>
</tr>
<tr>
<td>Inform</td>
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<td>.21**</td>
</tr>
<tr>
<td>Supervise</td>
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<tr>
<td>.16*</td>
</tr>
<tr>
<td>Rules</td>
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<tr>
<td>.25***</td>
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<tr>
<td>Encourage</td>
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<tr>
<td>.24***</td>
</tr>
<tr>
<td>Feedback</td>
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<tr>
<td>.21**</td>
</tr>
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* Sig of Gamma at .05
**Sig. of Gamma at .01
*** Sig. of Gamma at .001

Having described who typically mentors undergraduates, in what way, and why, we turn to findings about outcomes at the department level.
4.2 Research mentoring

Unsurprisingly, faculty engage in research mentoring with undergraduates most often in departments where quality is high – the quality of students, as measured by the median SAT score of incoming freshmen, and the quality of the CS program, as measured by 1993 NRC quality rating. The correlation between research mentoring and median institutional SAT score was 0.46, significant at the .001 level. For the NRC rating, the correlation with research mentoring was 0.27, significant at the .02 level.

Based on published reports about the value of research experiences for undergraduates [6], we expected that research mentoring would have numerous beneficial effects on students in departments where it was a common practice. In particular, we expected a positive association with grades, retention, and student progression to graduate school. We also anticipated that women’s enrolment and retention would benefit particularly from research mentoring. As it turned out, not all of our expectations about research mentoring were supported by our data.

There is a significant department-level relationship between research mentoring and one aspect of progression to graduate school. Research mentoring was positively associated with the quality of the graduate program students entered. The chance that most or all of the students who went directly to graduate school went to top-tier programs was highest in departments where research mentoring was prevalent, even when student quality and program quality were controlled. The more often faculty involved undergraduates in research, published with undergraduate co-authors, informed undergraduates of research opportunities, and supervised extra work, the more likely it was that students would go to excellent graduate programs, regardless of the quality of their undergraduate program or the general academic quality of students at their institution. (Adjusted R2 = 0.69, significant at .001 level, Beta for research mentoring = 0.19, significant at the .014 level.) The gender composition of the department’s faculty had no measurable impact on this relationship.

4.3 Support mentoring

We expected that support mentoring would help students succeed and persist. We also expected that departments where support mentoring was common would enrol women in relatively large portions, would retain women in the CS major, and progress large portions of women to graduate school.

We found evidence that support mentoring had the expected measurable effects only on progression to graduate school. Departments where it was common for faculty to provide support mentoring sent larger portions of their seniors on to graduate school than did departments where this form of mentoring was uncommon. Regardless of the quality of students or program, more support mentoring was associated with more students proceeding directly to graduate programs. (Adjusted R2 = 0.24, significant at .001, and Beta for support mentoring was 0.33 when controlling for SAT and NRC rating.) Neither the quality of the graduate programs to which students went nor the gender composition of the faculty had a measurable influence on this relationship.
We also observed an unexpected positive association between support mentoring and attrition from the major. Departments where support mentoring was common were more likely than those where support mentoring was not common to lose students to other majors, even when the median SAT and presence of female faculty were taken into account. This observation suggests that support mentoring was not generally sufficient for overcoming the conditions that led men and women to switch to other majors.

4.4 Motivated but unspecified mentoring

Finally, we considered the possibility that particular mentoring actions are less important to outcomes than are the motivations that underlie the actions. In particular, we tested whether diversity-motivated mentoring had gendered consequences independent of the specific mentoring activities performed. Based upon results from the average CS department, we expected that departments in doctoral institutions would also retain women at comparable rates to men when many faculty mentored students out of a desire for diversity.

Our results were very interesting, but not conclusive. In the 45 doctoral institutions that provided enrolment data, there was a moderately weak correlation between the percent of a department’s faculty that mentored for diversity and the gap between male and female attrition rates ($r = 0.24$, significant at $.06$). When we controlled for the factors significant in the average CS department, there were only 36 degrees of freedom, but the relationship persisted (Beta for diversity mentoring = .23, significant at .05). Furthermore, when research and support mentoring activities were also controlled, the relationship between diversity motivation and gendered attrition rate remained essentially the same but achieved a level of statistical significance (Beta for diversity mentoring = .30, significant at .01). The small number of cases and moderately weak relationship led to these results that waivered between being sufficient and insufficient for confident generalizing to all mid- to large-sized CS departments at doctoral institutions. However, the consistency of the relationship leads us to believe that diversity-motivated mentoring improves the relative retention of undergraduate women in CS at doctoral institutions.

5 Discussion

Mentoring has been associated with positive consequences for the individual students who are lucky enough to receive it. Student-faculty relationships that include activities promoting involvement in computing professions, helping students establish their careers, and providing personalized advice and encouragement could be very beneficial. Student protégés might earn higher grades, persist beyond any doubts or difficulties, and continue on to graduate school, all to a greater extent than students not in mentoring relationships with faculty. Mentoring might even help increase women’s participation in computer science. But unless faculty mentoring of undergraduates is a common practice, there would be no evidence of these department level benefits. Isolated efforts of
individual faculty would benefit a few students, but the big picture would remain the same – low grades, high attrition, few students proceeding to graduate study, and persistent gender disparity.

Our multi-institution research has two important strengths – benchmarks and evidence of some measurable large-scale outcomes associated with mentoring in CS. It also raises many questions and points to avenues for further exploration that cannot be adequately discussed in the available space. The benchmarks document common mentoring practices and motivations in the United States with special attention to the similarities and differences between men and women faculty. The hypothesis tests of department-level consequences from widespread mentoring showed that mentoring can mean more than its individual successes and failures. Perhaps this greater impact is why women’s presence and representation on a faculty demonstrated no measurable association with any of the large-scale outcomes associated with the prevalence of mentoring. As other studies have found, we saw that the material benefits of mentoring do not depend on who does it, only that someone does. Our study might add that some gender-balancing benefits do not depend on the particular forms that mentoring takes, only on the motivation that drives them.

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References


