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Female Students' Underachievement in Computer Science and Mathematics: Reasons and Recommendations

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Chaos in Computer Classrooms

Lesley S. Klein, instructor of information systems at Pace University and a computer science teacher in middle school and high school, described the chaotic state of computer science education throughout pre-college levels. Working under the auspices of the Board of Cooperative Educational Services, funded by New York State Department of Education, Klein observes upper middle income schools of this public school system. Despite its relative wealth, there is often a low budget for computer science and no curriculum, she said. Computing is taught by teachers' aides or by media center administrators who have had in-service training. "Occasionally students are fortunate to have a classroom teacher who has an interest in computers as a hobby or has taken some computer education courses," Klein reports in her paper, "Female Students' Underachievement in Computer Science and Mathematics: Reasons and Recommendations." "Some more adventurous teachers have incorporated LOGO or Lego Logo programming into the curriculum, but there is no apparent formal plan nor carryover from one grade level to the next," Klein continues. There are neither goals nor minimum standards established for both teacher training and the material to be covered. Not until the seventh and eighth grades does the study of computers, logic, or BASIC programming emerge. PASCAL and C programming and introductions to data processing are offered in secondary schools, but there is still great variation in instructors' backgrounds and levels of competence. Some are math teachers, have master's degrees in computer science, or have taken graduate courses, but others are industrial arts teachers who have received minimal training. On the other hand, sometimes industrial arts teachers are better qualified than math teachers. Although high school curricula for computer literacy and computer science courses do exist (ACM made several recommendations on curricula five years ago and plans to revise them by 1991) there is little support to implement them and there is no uniformity from state to state.

But one would expect this sorry state of affairs to affect boys and girls equally. Not so. According to Klein, girls "demonstrate more insecurity and lack of self-confidence in math and science during transition periods" like entering middle school and entering high school. In middle school, for example, boys use pirated software, she says, and the girls follow the school rules and are in the boys' way. "The computers are always consumed by the boys who rush in, desperate to continue where they left off the day before in Oregon Trail, Karateka, or Carmen San Diego. An occasional girl wanders in, but would practically need interference from the heavens to gain access to these monopolized computers," Klein says. Given these different styles of behavior, Klein sees the need for a formal computer science curriculum for grades seven through twelve as well as a mandatory requirement that every high school student take an introduction to computer science. Because many in the educational community are unaware that recommended curricula exist, Klein stresses the need for support for the distribution and implementation of curricula. In addition, there should be more uniform teacher training that improves computer skills and lesson presentation while "specifically addressing the motivation of female students."

"Female Students' Underachievement in Computer Science and Mathematics: Reasons and Recommendations" was presented at the annual National Educational Computing Conference (NECC) in June, 1990.

In addition to presenting this paper; Professor Klein was one of twelve scholars who participated, by invitation, in the special day-long workshop exploring the reasons for the underrepresentation of women within the major in computer science. (Dr. Carol E. Wolf, Chairperson of the Computer Science Department in New York, was also among the invited participants.)

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Female Students' Underachievement in Computer Science and Mathematics: Reasons and Recommendations

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FEMALE STUDENTS' UNDERACHIEVEMENT IN COMPUTER SCIENCE AND MATHEMATICS: REASONS AND RECOMMENDATIONS

by Lesley S. Klein

Research has shown that, overall, female students have a higher verbal self-concept than male students, yet lower self-concepts in their abilities in mathematics and computer science than boys. The following paper explores how self-concept and other factors, including traditional attitudes toward mathematics, teachers and parents, role models, and software design, influence girls' attitudes toward the study of computer science.

Introduction

My intrigue in boys' greater interest in computer science than girls' was born from four years of teaching computer science in a gifted education program for grades 5 through 11. Students are recommended for the program by teachers and guidance counselors. The prerequisite for acceptance is to pass a screening given by gifted education specialists who look for interest and aptitude in the subject area. In four years, the gender pattern has remained consistent. On the fifth grade level, the gifted class is approximately one-half girls and one-half boys. After the fifth grade, only male students have been identified as gifted in computer science.

When I visit computer labs in local schools and observe the clientele during "open lab" time, I frequently see an even distribution of boys and girls in elementary school, but there is a difference in their choice of software. The boys are often "shooting" gunfire at correct answers, winding a little man through a maze, or enthusiastically hunting for gold, criminals and other treasures, hoping to find their name at the top of the electronic score card. The girls are correctly answering math problems that reward them with a few bars of electronic music and a colorful picture, writing stories or a newspaper on a word processor, creating designs and engaging in adventure games merely to compete against themselves, without as much concern about their score card status relative to the other players.

In middle school, the computers are always consumed by the boys who rush in, desperate to continue where they left off the day before in Oregon Trail, Karateka, or Carmen San Diego. An occasional girl wanders in, but would practically need interference from the heavens to gain access to these monopolized computers.

The pattern of voluntary computer usage by girls improves on the high school level. While male attendance predominates, females have a smaller but significant showing. Girl programmers can be found, but males are more often enrolled in programming courses requiring them to work in the lab and are more inclined to program for enjoyment and experimentation rather than for the purpose of handing an assignment in on time, which is often the

reason that female students program during open lab time. Students of both genders frequently use word processors, but girls use the more sophisticated MacIntosh desktop publishing facilities than boys, who seem content using Appleworks on the Apple II series. I have never witnessed females participating in robotics projects, although in the fifth grade, girls were as interested as boys in Lego Logo (an introduction to robotics).

I have seen a wide variety of capabilities in the faculty who teach computer usage and programming. In lower grades, this is often the responsibility of a teacher aide or media center administrator who has had in-service training. Occasionally students are fortunate to have a classroom teacher who has an interest in computers as a hobby or has taken some computer education courses. Some more adventurous teachers have incorporated LOGO or Lego Logo programming into the curriculum, but there is no apparent formal plan nor carry over from one grade level to the next.

Not until the seventh and eighth grade level does the study of computers, logic or BASIC programming emerge. Finally, PASCAL and C programming as well as an introduction to data processing are offered in many secondary schools. Some teachers assigned to teach secondary computer education are knowledgeable and either hold Masters degrees in computer science, or have taken graduate courses, staying abreast of the most recent theory or technology. Others are math or industrial arts teachers who have received minimal training and support in their efforts to teach this relatively new and evolving subject.

The following section gives a description of significant studies of elementary, secondary and college students' attitudes toward computers, and is followed by suggestions for improvements in computer education.

Review of Literature

1. Self-Confidence in Mathematics and Computer Science

Female self-concepts continue to decline throughout middle and secondary school, and with them, their mathematical achievement declines as well.

A clarification of the various math skills that are traditionally least easily attainable for girls is necessary. Gender neutral math activities to impart these skills must begin at the elementary level before girls lose their confidence in their math ability. Math instruction should build confidence as well as skills and awareness. The skills in which female students need improvement are spatial visualization (including graphing), problem solving and applications, and logical reasoning.(17) These skills will provide a foundation for a future career in math or computer science, but are also useful in humanities pursuits such as psychology or economics.

Spatial skills include

1) Recognizing shapes and their relationships to each other.

2) Seeing relationships between two-dimensional and three-dimensional shapes
3) Recognizing properties of shapes.
4) Locating points on a plane (use of coordinate systems).
5) Using graphs and tables to sort and display information.

Problem solving includes:
1) Understanding numbers and numerical operators.
2) Applying numerical operations to real problems.

Logical reasoning includes:
1) Sorting and classifying
2) Deductive Reasoning
3) Combination Reasoning
4) Variable usage
5) Probabilistic reasoning (probability).

Why do girls begin primary school with equal self-concepts in math and at least equal achievement, only to avoid math computer classes in secondary school and college and eventually choose careers that do not involve mathematics? Presently our country is not scoring well on international academic tests in math and science, as compared with other countries, on the eighth grade level. Our students' proficiency seems to decline rapidly once beyond the level of "basic skills". If women had better math and science self-concepts, our scores on international tests would probably be heightened. In the following section I will sight sex differences in mathematical achievement in schools (middle through college), explore possible reasons for the differences and finally cite studies that show the relationship between students attitudes toward mathematics and those toward computer science.

A study was performed on male and female AP math students at Hunter College High School. (17) The mean score on the AP calculus exam was 0.55 points higher for the boys than for the girls (statistically significant). On average, males scored 55 points higher on the math portion of the SAT's than the girls in the class. On the math achievement tests, boys scored 26 points higher than girls on Level I and 13 points higher on Level II . Yet, the math G.P.A. for both sexes were virtually the same. The overall G.P.A. for girls was 1.7 points higher than for boys. Why is there such an inconsistency between standardized test scores and school average? Are the tests somehow biased or do teachers expect more from male students than female students in math? Is school achievement of girls higher than their standardized test scores indicated because they are more eager to please their teachers and diligent in handing in homework assignments? Do we encourage autonomous and creative thinking (important in higher level cognitive skills) less for our female high school students than the males?

The results of one international study reveals that sex

differences in math achievement tends to be cultural rather than caused by genetic differences. (1) The reason for this conclusion is that while girls in most nations scored lower than the boys of their own country, they had higher scores than boys of other countries (who in turn scored higher than the girls in their own country and so forth). While males excelled in math as compared to females overall, the male achievement level varied greatly from one country to another. The exceptions were amongst native Hawaiians, Filipino-Americans and Japanese-Americans amongst whom girls scored higher than their male counterparts.

Male dominated mathematical areas included measurement and proportion problems and generally questions that involved spatial relations. Males scored higher overall in problem solving, but females excelled in computational skills, abstract deductive reasoning and symbolic relationships such as sets.

Yet in the latest SIMS study (Second International Mathematics Study) a math test was administered to students in eight countries: Japanese seventh graders and eighth graders in Belgium, British Columbia, France, Ontario, United States, New Zealand and Thailand. Test questions were drawn from the curricula of each country, giving a fair balance of test questions. The categories included: fractions, ratio/proportion/percent, algebra, geometry and measurement. This time, there were no statistically significant differences overall between genders, although the greatest areas of difference were in fractions in which girls excelled and geometry in which boys excelled. Why is there a discrepancy between this study and the previous studies? Did cultural differences improve, or more likely, was this test (SIMS) better designed? The author of this recent study postulates that gender differences usually found in math performance are due to a blend of curricula, teaching methods and culture.

What happens to these girls who enter primary school with an even self-concept with boys by the time they reach college? A study was conducted on college freshmen to compare their attitudes toward math courses and future careers.(10) Men put higher value on math than women. According to the questionnaire results, women often gave "lack of interest" as their reason for not taking math courses. Also cited was womens' expected lack of success in math courses.

In a study by Kwan of students in the northeastern region of the United States (8), he hypothesizes that the reasons behind mathematics underachievement will be a clue to computer underachievement. The results of Kwan's study concluded that gender differences in interest in computers followed the same path as that of mathematics. Reasons include girls' low self-expectations, test scores, spatial ability and greater math/computer anxiety. In lower grades (pre-high school), students perceive both professions as male dominated and having less relevance to a woman's future career. Females are unmotivated by information they perceive as the memorization of rules rather than a creative endeavor; this is a statement to educators to improve their presentation of computer instruction. There is great opportunity for creativity in programming as a

problem solving tool.

Kwan found a more positive attitude toward computer science in his survey of female high school students enrolled in accelerated mathematics classes. They tended to reject the notion that computers are a male domain, but felt that the media too often portrayed it as such; and that computer knowledge would be useful in their future careers. Thus, according to Kwan, girls who experienced success in mathematics were more positive about the study of computers than the general population of female students.

Guinan and Stephens (4) conducted a study that suggests that gender was actually an independent factor in computer science achievement, while mathematics background and GPA were the primary factors. Their study compared male and female secondary students' success in two introductory computer courses: the first included flowcharting, coding and FORTRAN; the second involved basic concepts, history, and principals of computers. Girls preferred the latter course, while boys more frequently chose the former. If math background is a primary factor and the general population of female students suffer from more math anxiety and less experience, then gender does become a secondary factor.

II. Software Design

A study by Wilder(19) suggests that masculine software design is precluding girls from developing a sense of "ownership" toward computers, beginning with video arcade games. She observes boys domination video games while girls merely act as spectators. Other voluntary computer related activities demonstrate the same pattern including computer clubs and computer camps. Although the responses to his survey of elementary school children indicated that boys and girls did not have very strong attitudes regarding gender-related factors and computer interest, they did perceive them to be appropriate for boys, the boys indicating stronger feelings than the girls.

Perhaps the most significant aspect of Wilder's findings is that the interest in computers of both male and female students declines rapidly beginning in the sixth grade. A possible explanation for this is that computer instruction changes from "fun" applications to computer theory and more serious applications.

Hawkins addresses a different problem with software than its male orientation. (5) An elementary school class in which a teacher was instructed to be sensitive to the needs of unmotivated girls was given the opportunity to use the computer with three software packages: one measured physical data such as temperature, light and sound; the second was a simulation game for geometry and navigation; the third were a series of games to introduce LOGO programming. The second and third required collaboration among students in small groups while the first was designed for individual use. Teachers reported that girls preferred and participated voluntarily in the use of two latter packages which were socially oriented. Previous to this study,

the teacher had tried to introduce LOGO programming without the collaborative software. Girls were not as motivated as boys, even with a reward incentive of prizes for the best programmer, most improved, most enthusiastic, etc., which only the male students had obtained. After the study, a few girls earned these awards. Successful female programmers were good students in most academic subjects, yet this was not true of the successful male programmers.

III. Positive/Negative Feedback

Hawkins notes another observed factor during her study was the importance of the quality of feedback students received from their teacher. Female students lost confidence if there was little or no feedback more quickly than males, although it was not as important during social tasks as individual ones. As in the case of mathematics, a high degree of competition in the classroom setting was discouraging for females. Finally, she observed during the implementation of her study that when schools acquire hardware and software, they do not receive enough training and support for its use, confirming the findings of another study by Fetler. (2)

A revealing study was made of teacher responses to students on the fourth grade level. (11) Responses to students were categorized as positive feedback, recognize, move on, praise, explain/help, redirect and negative feedback. During math lessons, boys did not receive negative feedback in any activity. Responses to boys included recognition, positive feedback, explain/help, redirect, and one case of moves on (in order of most to least frequent). On the other hand, teacher response to girls in the same class were moves on, negative feedback, recognize, one case of ignore and one case of explain/help. Responses during reading class were completely different and obviously less sex biased.

Parental attitudes may influence a student's self-concept. A study was conducted to compare the math achievement of students whose parents had no college degree with students whose parents had a least a bachelor's degree.(6) The subjects were fifth through twelfth grade students, their mothers and their fathers. All were of middle/working class socioeconomic groups. A questionnaire was completed which questioned subjects on self-perception of their math ability and their expectations of taking math classes. They were asked about their parents' feelings towards math, including their ability, enjoyment, difficulty, and past attitudes toward high school math. Parents were questioned about their child's ability and effort in math.

Comparisons not only made between college and non-college educated families, but between same sex parent and child and opposite sex parent and child within the original two subgroups. Researchers expected to find positive correlations between all higher educated groups, but the only statistically significant group was mothers with higher education and a positive attitude

toward math and their daughters. The closest correlation centered around mothers past positive memories of high school math, not around their present self-concept. The author of the study theorizes two reasons for this: Firstly, their memories are invoked by observing daughters doing their homework, resulting in either sympathy or enthusiasm, but nevertheless support; secondly, math may not be part of the mothers present career demands.

The reason that fathers and sons do not have the same relationship is perhaps because fathers are not as willing to admit to any weaknesses in math and sons may not be willing to admit that they are struggling in math. Parents may not wish to "share" negative experiences in math with their sons, as not to be a negative influence. The study did not completely support the above assumption, but children of higher educated parents overall were more perceptive of their parents' attitudes toward math. Finally, the influence of mothers attitudes toward math on their daughters were independent of their expectations of their daughters accomplishments in math.

At some point in a child's development, he/she will identify particularly with the same sex parent. While I would not recommend dishonesty, mothers should not constantly bemoan their aversions toward math or computers if they have one. A constant droning of negative comments would certainly affect a daughter's attitude. On the other hand, if a daughter is in fact struggling with math, a mother who had the same feelings can sympathize, be supportive and share her experiences with her daughter. Hopefully the mother would find ways for her daughter to succeed that had not been made available to her, for instance private tutoring or computer software to sharpen math skills.

Gender differences in perception of encouragement from same-sex peers was statistically significant, with men rating higher, yet the differences in encouragement from opposite sex peers and parents was not statistically significant at this point in their lives. When the sample was questioned on expected enjoyment of college courses, women significantly responded more positively to social sciences and English while men responded more positively toward computer science and mathematics. Men expected to perform well in math courses, while women expected to do poorly. The results were the same when asked how he/she would succeed in relation to others in the class.

While women generally did not agree that mathematics was a "male domain", they reported more math anxiety; males had more confidence in their ability to learn math. When asked why they do not perform well in math, women attributed low ability and discouragement by others as the main reasons. The men perceived women as not as able to handle computers. The most discouraging result of this study is that men stated a significantly greater intention to take math courses in the future than women.

In the same study, college students were asked many questions about career choice. Men rated the opportunity to earn a high salary much higher than women, who focused on working with people, combining career and family and performing well on the job. Men agreed much more strongly than women with the following

statements: It is difficult for a woman to combine a scientific career and family life; that a woman chemist or physicist who takes time off from her career to have children will never catch up again; that a woman planning a career as a mathematician or scientist should plan not to have children and that a woman dedicated to a career in science or mathematics would not be able to devote much time to her family.

Unfortunately, only 11 out of the 251 female respondents of this study planned a career in either mathematics, physics, chemistry, computer science or statistics.

There is evidence to support the fact that skeptical attitudes of female high school students toward computers does not improve in college or in the workplace. (3,14,18) Many studies reiterate the finding that males perceive computer knowledge as more valuable to them in future careers than do females. Females more frequently use computers as a tool for electronic banking and mail, but males are more confident in their programming skills and feelings of "ownership" of computer skills. (15)

Miura found that experience in a high school computer course and current enrollment in a college computer course were the two most important gender independent factors in college computer course enrollment in her study to understand self-efficacy in gender differences in selecting college computer courses.(14) Yet, without voluntarily enrolling, female students can not gain the experience that inspires the self-confidence that leads to the pursuit of further computer course enrollment.

SUGGESTIONS

A starting point in rectifying the problem at hand is to clarify and formalize computer science curriculae on the pre-college level. Fetler states that both male and female students underachieve in computer skills due to the novelty of computer studies, lack of qualified teaching staff and confusion over what should be taught. (2) I have observed improvement in teachers' comfort and proficiency in teaching computer science over the past four years, but the "remain one step ahead of the students" method still prevails in classrooms that at least attempt to update their information. Many elementary and middle school classes continue to teach the same tired and poorly designed BASIC programs year in and year out.

Marsh suggests single sex (all female) accelerated or remedial math groups. (13) She also recommends identifying gifted female math students and supporting them with extra encouragement and opportunity to meliorate their talent. This could be in the form of computer classes and gifted math classes.

The following are suggestions for the improvement of computer education on the secondary and pre-secondary levels:

1. Introduction to computer courses should be required in secondary schools. Since previous experience with computers and computer courses lead to a more positive attitude towards

computer course electives, more female students may be ready to enter college as computer science majors if they have previous experience in high school.

2. Incorporate computer usage into school curriculae during transition periods (i.e. entering middle school and entering high school). During these years, female students demonstrate more insecurity and lack of self-confidence in math and science, which sets them behind male students in the remaining school years.

3. Develop a more consistent relationship between classroom teachers and educational software designers, stressing the need for less competitive software.

4. Incorporate group projects in the classroom as often as individual assignments. Projects should relate to issues of social relevancy due to female secondary school students' increased interest in socialization (i.e. design a program in Pascal or C that conducts a market research survey and tabulates and/or evaluates responses).

5. Incorporate greater use of telecommunications through which computer literacy is learned in conjunction with other stimulating educational projects.

6. Formalize curriculae to develop student interest in technology on all grade levels that carry over from one year to the next, rather than the present ad hoc references to technological advancements.

7. Provide a secondary computer science class in which problem solving is established as its purpose and program design and logic are the tools used for sharpening problem solving skills. The learning atmosphere should be non- competitive; teachers may find that grouping according to gender would increase female students' participation.

8. Invite women in industry to cooperate in projects with local schools, providing role models for female students.

CONCLUSION

There are a wealth of published studies that establish the fact that female students are overall less interested in computer science than their male counterparts for reasons of low self-efficacy, competition, identification of computers with math and science, male orientation of software, and inadequate computer education curriculae. Perhaps computers are perceived by students as a male domain because that is how they are presented in software, in the media and in the classroom.

A three step process can aid in the remedy of the problem: 1) the publication of a formal secondary level computer science curriculum for grades 7-12, 2) distribution of said curriculum and support for its implementation, 3) teacher training for

improvement of computer skills and lesson presentation, specifically addressing the motivation of female students.

On a personal note, I took my first computer course as a college elective in order to overcome my fear of technology and because I felt it would be beneficial to any career I might pursue. Success in my first programming class (taught by a woman with superior mathematics as well as communication skills) led me to a second programming elective, taught by another woman. At the end of the semester, the professor encouraged me to consider a career and enrollment in a graduate program in computer science and information systems. All of the positive elements were in my favor: encouraging feedback, female role models, confidence in my math skills, and the completion of two computer courses. I hope that we can impart the same support extended to me by that professor to our current and future female computer students.

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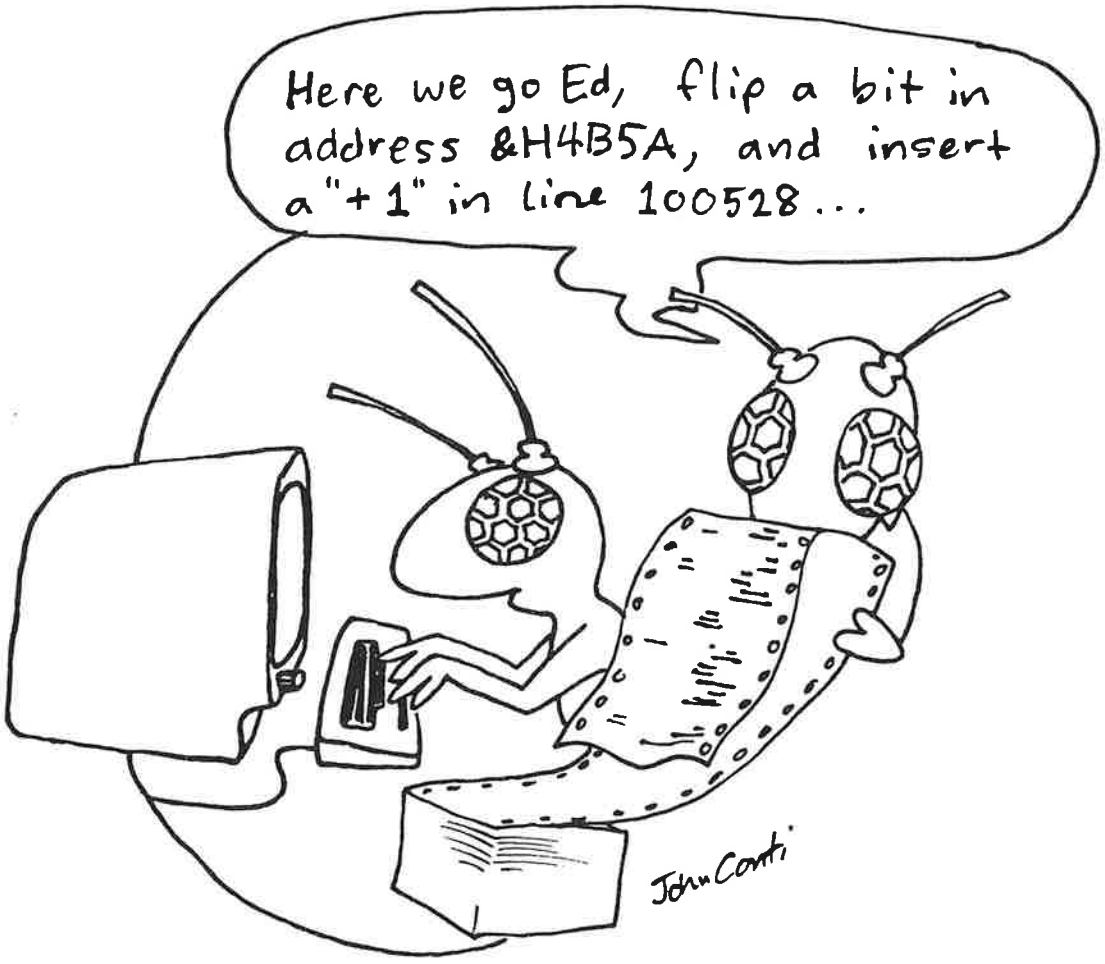
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