The Current State of Computer Science in U.S. High Schools: A Report from Two National Surveys

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Abstract

This paper addresses the results of two surveys conducted by the Computer Science Teachers Association between 2004 and 2008. The purpose of these two surveys was to collect foundational data about the state of high school computer science education in the United States. The paper provides a wealth of information with regard to the types and content of courses offered, trends in student enrollment (including gender and ethnic representation), and teacher certification and professional development. The results of these studies are consistent with current research pointing to issues of concern in such areas as the number of schools offering computer science courses, the engagement of underrepresented student populations, and the availability of professional development opportunities for computer science teachers.

1. Background

One of the challenges we face when discussing computer science education is that the field of computer science seems to evolve so quickly that it is difficult, even for computer scientists, to clearly define its contents and prescribe its boundaries. While we do know that computing now provides the infrastructure for how we work and communicate and that it has redefined science, engineering, and business, it is still poorly understood by those outside the field.

Both the boundaries and the content of computer science are constantly being reshaped. New thinking and new technologies continue to expand our understanding of what computer scientists can do and need to know. This has resulted in considerable debate about a single definition of computer science. The Association for Computing Machinery's *Model Curriculum for K–12 Computer Science*, however, provides a highly useful definition of computer science for high school educators. Computer science, it argues, is neither programming nor computer literacy. Rather, it is "the study of computers and algorithmic processes including their principles, their hardware and software design, their applications, and their impact on society" (Tucker et al., 2006, p. 2).

Unfortunately, though, there continues to be much confusion about computer science in K-12 education. Among those not familiar with the discipline, there is a tendency to confuse the study of computer science as a scientific discipline with other uses of computing technology within education, particularly computing literacy (the mastery of basic software applications), keyboarding, or educational technology (the use of computing to support learning in other curriculum areas). As a result, in many schools and countries, policy-makers and administrators are failing to provide students with access to the key academic discipline of computer science, despite the fact that it is intimately linked with current concerns regarding national competitiveness and the ability of students to thrive in an increasingly globalized knowledge economy.

Two other terms that often appear in discussions of computing education are *Information Technology Literacy* and *Information Technology Fluency* (National Research Council on Information Technology Literacy, 1999). As Tucker et al. (2006) indicate:

> Whereas IT literacy is the capability to use *today's* technology in one's own field, the notion of IT fluency adds the capability to independently *learn* and use *new* technology as it evolves…throughout one's professional lifetime and includes the active use of algorithmic thinking (including programming) to solve problems, whereas IT literacy is more limited in scope. (p. 6)

There can be no doubt that computer science is enabling a new world of discovery and progress across all of the sciences and a growing number of humanities fields (Emmott, 2006). According to his *Towards 2020 Science* report, there has been a fundamentally important shift from *computers* supporting scientists to "do" traditional science to *computer science* becoming embedded into the very fabric of science and how science is done. In this way, "computer science is poised to become as fundamental to biology as mathematics has become to physics" (Emmott, 2006, p. 10). Computer science is important to industry precisely because it leads to multiple career paths. It is also fundamentally important as an intellectual pursuit because it teaches computational thinking and problem solving skills that are foundational to all sciences and one might even argue to the humanities as well.

In 2005, the Computer Science Teachers Association (CSTA) was formed by the Association for Computing Machinery (ACM) in response to growing concerns about the state of computer science in high schools and what was already being perceived as a downturn in student interest in computer science as a field of study and a career destination. One of the first tasks undertaken by CSTA was to move beyond the anecdotal reports to a research-based view of the state of computer science in U.S. schools. To achieve this goal, CSTA has conducted two national surveys of computer science educators in the United States. The first survey was conducted in 2005 and the second in 2007. In 2008, CSTA also conducted a more granular analysis of the 2007 data, looking at the results reported for individual states. These two surveys were supported by funding from the National Science Foundation's Broadening Participation in Computing program and represent CSTA's ongoing commitment to providing regular and ongoing tracking of key trends in high school computer science education over time.

2. The Surveys

The following section reports on the methodology used and the result attained from two studies of high school computer science teachers conducted in 2005 and 2007 by CSTA. The two surveys were intended to create a more comprehensive and evolving understanding of high school computer science education.

2.1 Methodology

The two studies described in this paper were designed to elicit data on a number of core questions relating to high school computer science education. The 2005 and 2007 survey instruments were developed by CSTA's Research Committee and administered in fall 2004 and fall 2006. The subjects were drawn from lists of contacts provided by a market data retrieval company specializing in education. The target subject list consisted of all of the contacts in the database who defined themselves as computer science, computer programming, or AP computer science teachers.

The 2005 survey was mailed to 14,000 high school teachers across the United States. Participants were provided with the option of completing and submitting a paper-based version of the survey or completing the survey online (via SurveyMonkey.com). A total of 1,047 teachers responded to the survey (a response rate of 7.5%).

The 2007 survey was distributed in the spring of 2006 to 13,000 high school teachers. Notice of the survey was mailed to teachers across the United States and recipients were directed to an online survey instrument (SurveyMonkey.com). A total of 1080 teachers responded to the survey (a response rate of 8.3%), of which 950 were usable (the rest were eliminated because they were submitted by students, or people outside the U.S., or were incomplete).

The relatively low response rate, while not inconsistent with those achieved in other surveys, should be noted as it indicates a possible bias on the part of the participants. In the case of both surveys, teachers who are more interested in computer science education in general may be more likely to have participated in the study. In the case of the second survey, teachers who were more comfortable with, or had greater access to, the online survey could be more likely to participate and teachers who were uncomfortable with online surveys or did not have easy access might be less likely to participate.

The data provided by the participants for the 2005 survey were collected from both the paper-based and online responses and entered into a single Excel spreadsheet and analyzed using the spreadsheet's relatively simple quantitative tools to produce tabulated totals, averages, and means. Because the 2007 survey was conducted entirely online via SurveyMonkey.com, the researchers were able to utilize the quantitative tools provided by the survey application to generate the data analysis report. When the researchers examined the results of both surveys, they were able to make a number of observations, especially with regard to overall trends.

2.2 Results

The following section provides a comparison of the 2005 and 2007 survey results in several key categories. These include courses offered, course content, gender and enrollment, teacher certification, and professional development.

2.2.1 Courses Offered and Topics Covered

The 2005 data shows that while 78% of responding institutions offered what they described as a pre-AP course, only 40% offered an AP CS course. The 2007 data, however, show an alarming drop in the availability of computer science courses at both these levels, with 73% of respondents indicating that their school offered a pre-AP CS course and 32% of respondents indicating that their school offered an AP CS course (an overall decrease of 8% in the two years between surveys).

A comparison of the data from both surveys, however, provides some encouragement with regard to the number of students from each school who take the available CS courses. While in 2005 only 26% reported that students are required to take an introductory course, this number increased to 33% in 2007. The data also revealed an increase in the overall numbers of students enrolled in introductory CS courses in 2005 and 2007 from an average of 74 students per school to an average of 82 students per school (an overall increase of 10.8%).

Because the AP exam follows a set curriculum dictated by the College Board, no data was collected on the content of the AP CS course. The researchers, however, did attempt to determine the range of computing concepts being covered in courses that the responding schools designated as introductory computer science courses. When asked to indicate what topics were included in the pre-AP courses, the respondents from both surveys indicated that their pre-AP CS courses encompassed a variety of topics. Table 1 shows the percentage of schools that indicated specific topics.

Table 1

Topics Covered in Introductory CS Courses

	2005	**2007**
Problem solving	NA	62%
Graphics	46%	58%
Hardware	60%	57%
Ethics & social issues	56%	55%
Programming	68%	55%
Productivity software	NA	47%
Databases	35%	41%
Computer Security	14%	38%
Web development	43%	35%
Networks	21%	21%
Logic	11%	16%
Other	27%	18%

A comparison of the 2005 and 2007 results indicate that programming remains a central component of the introductory high school course for most schools, but that the number of schools that included programming in this course decreased from 68% in 2005 to 55% in 2007 (a somewhat surprising result considering this is supposed to be a computer science course). Interestingly, however, the 2007 results also showed that problem solving was the most commonly taught element of high school introductory computer science courses. In total, 62% of responding schools indicated that their curriculum for this course included problem solving (an encouraging result).

A comparison of the results between 2005 and 2007 also shows an increase in the percentage of schools including computer security as part of their introductory computer science course. In 2005, 14% of schools indicated a computer security component, while in 2007 this number jumped to 38% (an overall increase of 24%). Other course components showing increases between 2005 and 2007 were graphics (+12%), databases (+6%), and logic (+5%).

The 2007 survey also attempted to determine which computing courses, other than computer science, were being offered in U.S. high schools. The data revealed that many schools offer a variety of additional courses. The most common of these courses were web design (76%), computer graphics (53%), computer communications (43%), and networking (41%).

2.2.2 Gender, Equity, and Trends in Enrollments

The 2005 results relating to gender in pre-AP and AP CS courses are very clear. They indicate that while 32% of the students taking the pre-AP course are female, the number drops to 23% for the higher-level AP course. The results for 2007 are even more disturbing, with only 17% of female test takers (an overall decrease of 6%). The introductory computer science course did not evidence a similar drop between 2005 and 2007, with the percentage of female students remaining steady at 32%.

These results are consistent with earlier research (Margolis, et al., 2008) and published data (Report to the Nation, n.d.) (not necessarily the same numbers, but both showed the decrease in female enrollments in computer science courses). These results also echo current studies showing that the numbers of women in computer science decline as women move through the academic pipeline (Taulbee, 2008). It does, however, contravene other studies showing that “once she makes it, she is there” (Gal-Ezer, Vilner, & Zur, 2007, p. 1). The lack of consistent results across these studies can be seen as further evidence that our understanding of the causes of and solutions for the gender inequity challenge in computer science education is still incomplete.

In 2007, the researchers added an additional question regarding the representation of minority (non-white) students in computer science as they felt it was important to try to put some actual data to the growing concern over the continuing under-representation of minority students, especially in light of the fact that an increasing percentage of high school students (and in some cases the majority of high school students) in many U.S. states are minority students. The survey results indicated that 24% of the students enrolled in introductory CS are members of an ethnic minority, while 22% of the students enrolled in AP CS are ethnic minority students. The survey data also revealed that in 2007, 15% of the respondents spoke a language other than English at home. These results therefore provide support for the increasing focus on programs aimed at encouraging more young women and ethnic minority students to study computer science.

The findings regarding the overall enrollment trends are not as clear-cut as those concerning gender and minority equity. The survey results are split almost evenly between respondents who indicated that enrollments had increased and those who indicated that they have decreased over the past five years. (It is interesting to note that the national data is consistent with the data from the individual U.S. states, indicating that even within a given state, enrollments are increasing in some schools and decreasing in others.)

Although it is not possible to extrapolate the exact cause of these inconsistencies from the data at both the national and state levels, it does provide us with a possible explanation. When asked directly why students do not take CS courses, a large number of respondents indicated that the problem arises from competition between computer science courses, which are almost always elective courses, and other core or mandatory courses that all students must take. The respondents also noted the lack of availability of courses (either because they had never been offered, or because they have recently been eliminated), and the fact that many students mistakenly believe that there are limited job opportunities due to off-shoring. This data has important ramifications for programs or institutions interested in developing strategies for increasing the number of CS enrollments.

2.2.3 Teacher Certification

The responses to questions relating to computer science teacher certification even within individual states (half of the respondents in any given state indicating that there are no certification requirements for teaching computer science and half reporting that there are) demonstrate that there is considerable confusion about certification requirements among teachers. This conclusion is supported by later research (Khoury, 2007) that indicated that the confusion with regard to computer science teacher certification in each state extends even to the level of the educational policy-makers and administrators responsible for enforcing certification requirements. It has also been validated by a recent CSTA white paper that proposes a multi-pathway model for computer science teacher certification (Ericson et al., 2008)

2.2.4 Teaching and professional development

The survey respondents identified a number of challenges that they believe make teaching computer science difficult. Rapidly changing technology was the highest-ranking challenge in both the 2005 and 2007 survey results. More teachers also noted the lack of student interest/enrollment and the lack of staff support as a key issue in 2007 than in 2005. Interestingly, fewer teachers gave high rankings to the lack of hardware and software resources in 2007 than they had in 2005. And perhaps most importantly, the lack of curriculum resources dropped from second place in the ranking of 2005 to fifth place in 2007.

The survey results between 2005 and 2007 showed very little change with regard to teachers' professional development challenges and preferences. As Table 2 shows, lack of adequate time for training remained the highest ranked professional-development challenge from 2005 to 2007. Opportunities for training, cost, and facilities and resources were also cited.

Table 2
Professional Development Challenges

	2005 Ranking	2007 Ranking
Time for training	1	1
Training opportunities	2	2
Training cost	4	3
Facilities and resources	3	4
Other	5	5

As Table 3 shows, teachers also continue to rank workshops and seminars as the most effective means for delivering professional development to teachers.

Table 3
Professional Development Effectiveness

	2005 Ranking	2007 Ranking
Workshops / seminars	1	1
Networking with others	4	2
Professional conferences	3	3
Online resources	2	4
College courses	5	6

3. Conclusion

Although limited to a single country, the results of the two CSTA surveys detailed above point to some interesting trends which may or may not be present in other countries, but which certainly warrant further investigation.

3.1 Future trends

The results of these studies appear to indicate a continuing and troubling decline in student interest in computer science courses in high schools. The significant drop off in student numbers between the first and second high school course can be seen as an indication that the first courses fail to catch the students' interest and discourage them from further study in this area. However, in the case of declining student participation in the CS AP exam, the data may actually be an indication that either the AP course itself dissuades students from taking it or that there are significant systemic issues that make it difficult or unwise for students to take the more advanced course. For example, anecdotal evidence collected by CSTA indicates that students choose not to take the AP CS course because they cannot fit it into their already overcrowded academic schedule and that they do not believe that post-secondary institutions value the successful completion of an advanced level computer science course to the same extent that they value courses in other scientific disciplines.

The continuing under-representation of both women and ethnic minority students in U.S. high school computer science courses is also a concern, especially in light of the growing number of ethnically diverse students in these schools. The data provided in these studies indicates an ongoing inability of the discipline to attract a diverse population of students, which is a particularly serious concern in countries where the need for highly skilled computer scientists is already outstripping the number of students in the academic pipeline.

3.2 Possible remedies

The results of these two surveys support other current research (Margolis et al., 2008) indicating that there are profound systemic problems in high school computer science education in the U.S. The confusion regarding teacher certification requirements is symptomatic of widespread problems with computer science teacher certification nationally (Ericson et al., 2008). Resolving these problems would require the state government to undertake an improvement and rationalization project similar in scope to the project currently underway to define a common set of curriculum standards for all states in core subject areas. A possible place to begin this process would be widespread adoption of the certification criteria set forth in the CSTA report entitled *Ensuring Exemplary Teaching in an Essential Discipline* (Ericson et al., 2008).

While the issues relating to course access and the under-representation of female and minority students are exceedingly complex, the system intervention developed by Jane Margolis and her team at the Computer Science Equity Alliance in the Los Angeles Unified School District Margolis is producing very promising results. Margolis' work, in fact, has established a powerful model for multi-level model for systemic intervention that shows potential for replication on a national level.

The results of the survey also indicate that access to relevant on-going professional development for computer science teachers is problematic despite the current focus on ensuring that all teachers are exemplary teachers. Although there are a few programs that attempt to address this issue by providing workshops for teachers (e.g., CSTA's Teacher Enrichment in Computer Science program and the CS4HS summer workshops offered by several universities including Carnegie Mellon and the University of Washington), it is clear that a more profound engagement with this issue is required. What is needed is a national commitment involving a multiplicity of partners at various educational levels to focus on ensuring that all computer science teachers have access to on-going professional development experiences that are grounded in current research regarding best practices for adult learning.

3.3. CSTA's Ongoing Commitment

The two surveys detailed in this paper represent CSTA's ongoing commitment to providing research-based information on the state of high school computer science education. This survey instrument will be disseminated again in 2009, and the results should be available for the beginning of the 2010 school year. In the meantime, the researchers hope that other, similar studies are being conducted in other countries so that it will be possible to collect and share data that provide insight into high school computer science education globally.

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