Computer Science Teacher Preparation is Critical

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I n this paper, we report on the research and recommendations of the CSTA (Computer Science Teachers Association) Teacher Certification Task Force, addressing the crisis in computer science teacher preparation and certification. This paper will address the importance of computer science as a scientific discipline, and provide a brief discussion of the relevant research and current existing certification models Primarily, however, this paper focuses on the Task Force's recommended models for teacher preparation and certification in computer science.

INTRODUCTION

1 Although it is often perceived, especially in secondary schools, as simply programming, computer science is far more than this. Every child in every classroom, every teacher in every school, and every person in every community is affected by technology, and the roots of technology were based on the fundamentals of computer science. We believe that a fundamental understanding of computer science enables students to be not only educated users of technology but also presents them with the possibility of designing and building our future technology tools.

Computer science education is strongly based upon the higher tiers of Bloom et al.'s cognitive taxonomy [Bloom, 1956] as it involves design, creativity, problem solving, analyzing a variety of possible solutions to a problem, collaboration, and presentation skills. These skills allow students to express their ideas in ways that will prepare them for the competitive world in which they live and begin to provide them with the knowledge they will need to use computers to improve the quality of life for everyone.

There is also a critical link between computer science education and the economic issues that an increasing number of countries are facing in light of the new global economy. The U.S. economy, for example, is expected to add 1.5 million computer- and information-related jobs by 2012. The U.S. education system, however, is not producing enough highly skilled people to fill these critical positions. Current projections indicate that the U.S. will have only half that many qualified graduates. Countries that do not address these deficits immediately and vigorously will face long-term skills shortages that will cripple both academic computing and their high tech industries. They will be seriously compromised in their ability to maintain or improve their positions in computing, communications, information science, and engineering. In addition, they will be unable to capitalize on current and future innovations that are already providing untapped economic and social opportunities.

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2 BACKGROUND

This section will examine the issues relating to computer science as a scientific discipline in general and to teacher certification in specific.

2.1 Computer science: A scientific discipline

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 to clearly define its contents and proscribe its boundaries. As Shackelford (2005) noted in his presentation *Why can't smart people figure out what to do about computing education?* even computer scientists find it difficult to reach consensus on a single, unified definition of the discipline. The ACM *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, 2003] Computer science therefore includes: programming, hardware design, networks, graphics, databases and information retrieval, computer security, software design, programming languages, logic, programming paradigms, translation between levels of abstraction, artificial intelligence, the limits of computations (what computers can't do), applications in information technology and information systems, and social issues (Internet security, privacy, intellectual property, etc.). *Computer Science*, in contrast to Information Technology or Educational Technology, spans a wide range of computing endeavors, from theoretical foundations to robotics, computer vision, intelligent systems, and bioinformatics.

Computer Science is important to industry, it is important intellectually (as already hinted above), it teaches problem solving skills, and it leads to multiple career paths. 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. As the *Towards 2020 Science* report [Emmott, 2006] notes:

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> We believe that computer science concepts and tools in science form a third, and vital component of enabling a "golden triangle" to be formed with novel mathematical and statistical techniques in science, and scientific computing platforms and application integrated into experimental and theoretical science (p. 8).
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This report however, uncovers 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, creating what we are prepared to go so far as to call 'new kinds' of science. Indeed, we believe computer science is poised to become as fundamental to biology as *mathematics has become to physics* (p. 10).

As the report also indicates, however, achieving this vision also requires fundamental changes to education to ensure that students are both inspired and prepared to thrive in this increasingly technological future.

Much of the recent discussion concerning pre-college education relates to the need to ensure that all students are provided with the appropriate knowledge in the sciences. This requires a rigorous and well-established computer science curriculum (such as the ACM *Model Curriculum for K–12 Computer Science*). It also demands computer science teachers who posses the technical, pedagogical, and methodological skills required to teach computer science in a way that truly engages students.

2.2 The crisis in computer science teacher certification

Within most educational systems internationally, the task of ensuring that teachers are adequately and appropriately prepared to teach a given discipline at a specified education level rests with the bodies responsible for teacher certification. These bodies must determine not only what teachers need to know in order to be certified educational professionals, but how that knowledge should be measured. For computer science teachers, however, the challenge of becoming and remaining exemplary educators is exacerbated by systems of pre-service education and teacher certification that are profoundly disconnected from the discipline of computer science and the needs of computer science teachers and students.

The current crisis in computer science teacher certification can be attributed to two key factors:

- A lack of clarity, understanding, and consistency with regard to current certification requirements, and
- A lack of connection between existing certification requirements and the actual content of the discipline.

Research has shown that, in the United States at least, teachers are profoundly confused about the certification requirements in their own states. Because many of those responsible for creating, implementing, and enforcing policies relating to teacher certifica-

tion do not understand the discipline and its theoretical, practical, and pedagogical underpinnings, they also tend to confuse computer science with other subject areas such as Technology Education/Educational Technology (TE/ET), Industrial or Instructional Technology (IT), Management Information Systems (MIS), or even the use of computers to support learning in other subject areas. As a result, the certification requirements are often poorly understood, poorly applied, and in some cases so poorly designed as to be incomprehensible even to those responsible for maintaining them.

The deficiencies relating to computer science teacher certification begin as early as the teacher preparation program. Because so few countries or states/provinces require or allow for teachers to be certified specifically as computer science teachers, very few teacher preparation institutions provide programs with rigorous and relevant computer science training. In the absence of clear and specific requirements for computer science, these institutions have little or no incentive to address the needs of computer science teachers.

Because they cannot be certified as computer science teachers, new teachers find that they must first meet the certification requirements in some other discipline, requiring them to develop and prove teaching proficiency in a field in which they do not actually wish to teach. In some cases, where teachers can receive an additional endorsement to teach computer science, the content they are required to master may have no more than a tangential relationship to what is needed to teach in a computer science classroom.

In many cases, teachers who clearly have the requisite knowledge and skills (for example those with both current teaching credentials and post-secondary degrees in computer science) are unable to be certified in computer science, while those with vocational or business certification but no computer science background are. In addition, while there needs to be a reasonable process for individuals who wish to transition from careers in the high tech industry to teaching, it is equally essential to ensure that they posses strong teaching skills as well as technical skills.

Where there is no system of computer science certification or endorsement in place, teachers with little or no computer science training are also frequently assigned to teach computer science courses. Without these teachers, many students would have no opportunity to learn computer science. But the continual struggle to stay one step ahead of the students in a constantly changing discipline takes an enormous toll on even the most dedicated educators.

RESEARCH REVIEW

3 Because computer science is a relatively young and still evolving discipline, there is limited research specifically addressing the preparation and certification of computer science teachers. What the existing research does tell us, however, is that computer science teachers [Roberts & Halopoff, 2005] and administrators [Khoury, 2007] alike are baffled by the current mismatch between the educational requirements of the discipline and the practical requirements embedded in current teacher certification requirements.

Despite the fact that the research relating to the kinds of knowledge that computer science teachers require (subject matter knowledge, pedagogical knowledge, and curricular knowledge) is both clear and consistent [Collins, Bercaw, Palmeri, Altman, Singer-Gabella, & Gary, 1999; Kahan, Cooper, & Bethea, 2003; Shulman, 1986; Wilson, Shulman, & Richert, 1987; Zeidler, 2002; Zohar, 2004] as is the research relating to the importance of methods courses [Anderson,1997; Ebby, 2000; Lapidot, & Hazzan, 2003] and of interweaving theory and practice [Jaworski & Gellert, 2003; Pietig, 1997; Shulman, 1990] into the experience of pre-service teachers before they become responsible for classrooms of their own, there appears to be very little indication in research that these factors are given sufficient (if any) weight in current certification requirements and hiring practices.

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LOOKING AT CURRENT SELECTED MODELS

4 In order to get a more detailed perspective on teacher certification issues for computer science we will present briefly the certification requirements in three states in the US, as well as in Scotland, and in Israel.

In **Pennsylvania**, computer science courses are offered in the Business, Computer and Information Technology (BIT) department and cross listed with the Mathematics department. Computer science courses offered are Programming and Advanced Placement Computer Science A and AB. Pennsylvania does not have certification or endorsement in computer science. Computing courses are taught by teachers with certificates in

- K–12 Business, Computer and Information Technology (BIT) http://www.pde.state.pa.us/teaching/lib/teaching/033_BusinessComputerInformationTechnologyCSA_0603.pdf
- 7-12 Mathematics -http://www.pde.state.pa.us/teaching/lib/teaching/050_MathematicsCSA_6800.pdf
- K–12 Technology Education - http://www.pde.state.pa.us/teaching/lib/teaching/065_TechnologyEducationCSA_6075.pdf

In **Georgia**, computer science courses are offered in the Business and Computer Science Program under the Career, Technical, and Agricultural Education Division. In the fall of 2007, a new

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computing pathway was adopted based on the *ACM Model Curriculum for K–12 Computer Science*. Students who wish to specialize in this new computing pathway must take the following courses: Computing in the Modern World, Beginning Programming, and Intermediate Programming. They must also take one additional course which could be Advanced Placement Computer Science A or AB, or a course in the Web Design pathway. The Georgia Professional Standards Commission (PSC) adopted a voluntary Secondary Computer Science Endorsement. Teachers can add this endorsement to any existing level 4 or higher secondary professional teaching certificate. See http://www.gapsc.com/TeacherEducation/Rules/Rules.asp for more information on this endorsement.

In **Texas**, computer science courses are offered in the Technology Applications department which is also called Career and Technology Education (CATE), but they may be also listed in the Mathematics department. In order to teach Computer Science in Texas, teachers need to hold either the Computer Science 8-12 certificate (current) or the Secondary Computer Information

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Systems, Grades 6-12 certificate (no longer issued). Information on the requirements for the Computer Science 8-12 certificate is available at http://www.texes.ets.org/assets/pdf/testprep_manuals/141_compsci8_12_55076_web.pdf

Computer science teachers in **Scotland** need to have completed:
- a four-year course leading to a bachelor of education degree; or
- a combined degree (sometimes known as a joint or concurrent degree); or
- a Professional Graduate Diploma in Education (PGDE) course following their bachelors degree (http://www.scotland.gov.uk/Publications/2005/11/2595850/58512#5).

In addition, computer science teachers must have a degree with 80 credit points (including 40 credit points at the Scottish Credit and Qualifications Framework Level 8 or above) from at least two of: Computer Systems, Software Development, Databases or Information Systems. The other 40 credits are required in any

computing area relevant to the computing curriculum in Scottish schools. A number of university degrees and postgraduate diplomas meet these requirements.

In **Israel**, computer science teachers are required to meet a rigorous set of criteria, which include a formal undergraduate computer science degree and graduation from a teacher preparation program. University Computer Science departments provide courses for students seeking a computer science degree as well as for teachers preparing to teach computer science in schools. Teacher preparation programs are offered either by Computer Science departments or by Education departments or schools, or by Science Teaching departments. A detailed description of one of the teacher preparation programs offered in Israel can be found in Gal-Ezer, J. & Zur, E. (2007).

5 RESULTS AND RECOMMENDATIONS

This section examines the need for a multi-level model of teacher certification that will take into consideration the multiple pathways by which individuals may enter the teaching field in general and computer science in specific.

5.1 A multi-level model to meet diverse needs

The most pressing questions, when considering teacher preparation and certification, are what knowledge must the teachers have in order to teach effectively and how and when should they acquire that knowledge. A series of frequently cited papers by Shulman (1986) and Wilson, Shulman, and Richert (1987) for example, identify several types of knowledge that teachers must have. These include:
- Content knowledge,
- Knowledge of other content (how computer science is used in other disciplines),
- Knowledge of learners, and
- Knowledge of educational aims and general pedagogical knowledge.

In contrast with traditional programs that used to emphasize pedagogical knowledge, Shulman (1986) argues that teacher preparation and certification programs should focus on teachers' content knowledge. For him, content knowledge is much more than a set of rules, truths, and procedures. Rather, it concentrates on three critical domains:
- Subject matter knowledge,
- Pedagogical content knowledge, and
- Curricular knowledge.

It is absolutely essential that all computer science teachers, new and veteran, have adequate preparation to teach computer science successfully. However, it is equally important that we do not drive good dedicated teachers who are already teaching computer science away from the discipline or even the classroom. The challenge for any model of teacher certification, therefore, is to find a way to deal fairly and respectfully with our existing teaching community, while at the same time ensuring that they are prepared to be the best computer science teachers they can be, all in line with the points mentioned above.

Although the populations from which we draw our computer science teachers are diverse (creating a wide continuum of expertise and experience), we believe that any preparation program for computer science teachers must include the following four major components.

1. Academic requirements in the field of computer science,
2. Academic requirements in the field of education,
3. Methodology (a methods course) and field experience, and
4. Assessment to document proficiency in general pedagogy.

In the present educational structure, the minority of K–12 teachers are veteran teachers with a certification in computer science and teaching experience. The majority of K–12 computer science teachers are drawn from one of the following constituencies:

- new teachers: presently college or university students working towards their first teacher certification,
- veteran teachers with a certification in another area that have never taught computer science,
- veteran teachers with a certification in another area that have experience teaching computer science, and
- Individuals coming from business with a computer science background and no teaching experience.

To address this diverse group of incoming teachers, the CSTA Certification Task Force report [Ericson, Armoni, Gal-Ezer, Seehorn, Stephenson, & Trees, 2008] introduces a multi-level model which provides the requisite knowledge (both technical and pedagogical) for computer science teachers. The following section summarizes the current work and provides a snapshot of the multi-level model they are proposing.

5.1.1 New teachers

Degree: A bachelor's degree or higher in computer science or a minor in computer science

Academic and Field Experience
- A seminar-type course that includes the history of computer science, the nature of the field and its relationship with other disciplines, the various computer science curricula on both high school and college/university levels
- Writing a research paper in the field of computer science education

Academic requirements in education
- Curriculum design and development
- Educational Psychology
- Technology in the classroom

Methodology and field experience
- Methods course
- Class observations and a minimum of 10 weeks practice teaching

Assessment to document proficiency in general pedagogy
- Praxis II: Principles of Learning and Teaching Exam or equivalent satisfactory performance on a similar assessment to document proficiency in general pedagogy

5.1.2 Veteran teachers with no computer science teaching experience

Degree: A bachelor's degree or higher in a field other than computer science

Certification
- Certification in an academic discipline other than computer science

Academic and Field Experience (to be completed within 3 years)
- Academic requirements in the field of computer science include advanced coursework in the following areas: programming, object-oriented design, data structures and algorithms, computer hardware and organization, computer applications
- Methodology requirements can be documented by the completion of at least one of the following: Methods Course, Auditing of two complete K–12 computer science courses

5.1.3 Veteran teachers with computer science teaching experience

Degree: A bachelor's degree or higher in a field other than computer science

Certification
- Certification in an academic discipline other than computer science

Computer Science Teaching Experience in:
- Teaching an Advanced Placement Computer Science course (or the equivalent) for at least two years, and/or
- Teaching International Baccalaureate HL Computer Science (or the equivalent) for at least two years, and/or
- Teaching a rigorous introductory computer science course (equivalent to the Level II course described in the ACM Model Curriculum for K–12 Computer Science) for at least two years

Academic Work and Field Experience (to be completed within 3 years)
- Academic requirements in the field of computer science can be documented by completing one of the following:
  - Completion of a minimum of 40 hours of professional development workshops designed for teachers of computer science
  - Advanced coursework in the following areas: programming, object-oriented design, data structures and algorithms, computer hardware and organization, computer applications
- Methodology requirements can be documented by the completion of at least one of the following:
  - Completion of a minimum of 40 hours of professional development workshops designed for teachers of computer science.
  - Methods Course
  - Auditing of one complete K–12 computer science course
  - Creating a portfolio that documents pedagogy in the computer science classroom

5.1.4 Individuals coming from business with a computer science background

Degree
- Bachelor's Degree or higher in Computer Science
- Bachelor's Degree or higher in a related field including:

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Bioinformatics, Computer Information Systems, Computer Programming, Computer Systems Engineering, Database Systems, Electrical Engineering, Information Science, Information Systems Design, Information Technology, Mathematics, Networking, Robotics, Software Engineering

- Undergraduate minimum 2.5 GPA on a scale of 4.0
- Undergraduate minimum 3.0 GPA in major field on a scale of 4.0

Work Experience

- A minimum of two years related work experience within past five years

> # There is a significant lack of consistency
> in computer science teacher certification standards in the United States and other countries worldwide.

Academic Work (a total of 18 college/university credits) *and field experience* (to be completed within 3 years)

- Academic requirements in the field of computer science include advanced coursework in the following areas (minimum of 3 credits): programming, object-oriented design, data structures and algorithms, computer hardware and organization, computer applications
- Academic requirements in the field of education (minimum of 9 credits): Curriculum design and development, Educational Psychology, Technology in the classroom
- Methodology and field experience:
  - Methods course (3 credits)
  - Class observations and a minimum of 10 weeks practice teaching
- Praxis Exam
  - Praxis II: Principles of Learning and Teaching Exam or equivalent satisfactory performance on a similar assessment to document proficiency in general pedagogy.

6 SUMMARY

There is a significant lack of consistency in computer science teacher certification standards in the United States and other countries worldwide. The standards for computer science licensure, a computer science teaching endorsement, and alternate licensure in computer science that are presented in this paper are designed to assist the governmental authorities responsible for issuing licenses to qualified education professionals. The ultimate goal of this effort is to ensure that the standards for

computer science teachers are clear, consistent, and are uniformly implemented in the United States as well as in other countries. It is critical that these standards be universally accepted and applied to the licensing of high school computer science teachers. **Ir**

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