School Level Computer Science Education and Computer Science Teacher Training in the US: An Overview and an Example Solution

Abstract: Future economic growth and prosperity of the US rely heavily on the strength and skills of the IT and computing workforce that will be able to expand and maintain the nationwide IT infrastructure. Unfortunately, the drop in standard of school level CS education over the last several decades threatens the United States’ capability to expand and maintain the nationwide IT infrastructure. Recent studies show the quality of CS education falling far short of the standard set by the ACM, and CS teacher certification programs being available only in a minority of states in this country. The measures undertaken by the state of Georgia to improve school level CS education is described along with the structure and implementation of a CS teacher endorsement program by Columbus State University.

Introduction

Computer science (CS) and technology is becoming an indispensable part of every sector of modern life. Service, development and maintenance of the existing hi-tech industries and future innovations in science and technology are at the center of global economy, creating a huge demand of CS and information technology related workforce [1, 4, 5]. Countries unable to meet this demand will face significant risk of compromising their economic growths. The situation in the US in this regard is quite concerning. While 1.5 million jobs related to computer science and technology are expected to be created in the US by 2012, it is estimated that only half of that many graduates will be produced by that time [2]. Paradoxically enough, standard of K-12 CS education has been significantly underdeveloped despite the growth of computer science and technology over the last few decades [ref]. As a consequence of inadequate CS training at school level, many CS major students at college are unable to successfully complete the education. A dramatic decline in the number of students enrolled in computer science at undergraduate level has been observed [2] over the last few years. In a search for answer, the Computer Science Teachers Association (CSTA) has conducted a number of rigorous studies and surveys on the status of school level CS education and teacher training in various states of the country [6, 7, 8]. These studies reveal that two major factors contribute to the growing crisis – lack of understanding of computer science as a discipline of study and lack of properly trained CS teachers. Computer science is not included in core academic subjects in many schools in the US [2, 3, 6, 7]. Schools that do offer computer science courses view computer science only as programming and computer applications, thus narrowing down the scope of CS education at school to a great extent [2, 7]. This process in turn reduces the number of potential CS students as students remain unaware of the full range of computer science as a discipline of study. This problem is further aggravated by the fact that computer science is mostly taught by teachers without any formal background and training in the field [reference]. A 2004 survey conducted by CSTA revealed that CS teacher certification requirement and procedure vary widely from state to state and there is sufficient inconsistency in rules and administrative structures within a state as well [8, 9].

The gradually declining interest of undergraduate students in CS education together with the deteriorating quality of CS education in secondary schools indicates that an immediate reform in school level CS education is a must in order to increase technology workforce in near future. As a response to this national crisis of CS education, the ACM K-12 task force curriculum committee constructed a rigorous model curriculum for computer science at all school levels [10]. This model curriculum encompasses all fundamental concepts of computer science with an increasing depth from elementary to high school. If implemented properly and taught by qualified teachers, this curriculum prepares students for successful computer science/IT career. Unfortunately, as CSTA found out, the
Adoption of ACM Model CS Curriculum for K-12

A major factor contributing to the nationwide decline of interest in CS among high school graduates is the lack of a standard CS curriculum at school levels. Computer science is not included in the core academic curriculum in most schools in the US. Schools that do provide CS education focus mostly on programming and computer literacy. As a result students often do not get the prior training required for successful completion of undergraduate CS education. In order to solve this problem, ACM launched a model CS curriculum in 2003 to set the context for computer science within K-12 education. The goal of this exercise was to provide a framework for state departments of education and school districts to address the educational needs of young people and prepare them for professional opportunities in the 21st century. This model curriculum defines the national standard of school level CS education with a focus on fundamental concepts of computer science. According to [10], this framework has the following general objectives:

- The curriculum should prepare students to understand the nature of computer science and its place in the modern world.
- Students should understand that computer science interleaves principles and skills.
- Students should be able to use computer science skills (especially algorithmic/computational thinking) in their problem-solving activities in other subjects (for example, the use of logic for understanding the semantics of English in a language arts class).
- The computer science curriculum should complement IT and AP computer science curricula in any schools where they are currently offered.

The proposed framework classifies the curriculum into 3 levels:

- Level I – This level is for grades K – 8 and introduces elementary school students to fundamental computer science concepts and simple algorithmic thinking.
- Level II – This is recommended for grades 9 or 10 and introduces students to a coherent and broad understanding of the principles, methodologies, and applications of computer science in the modern world.
- Level III - This level is recommended for grades 10 or 11. At this level students build up their knowledge on mathematical principles, algorithmic problem-solving and programming, software and hardware design, networks, and the social impacts of computing.
- Level IV – This level is designed for grades 11 or 12. At this level students can choose one particular area of computer science for in-depth study.

This framework is further broken down into appropriate learning standards for various grades. This model curriculum, if implemented properly and taught by qualified teachers, is expected to provide students with adequate knowledge of computing that will lead students to successful completion of college level CS education.

Unfortunately, despite a national level effort for preparing students to succeed in the 21st Century, most US states have not yet adopted this model CS curriculum in high school academics. A state by state study conducted by CSTA reveals only 14 US states have adopted the CS education standard to a significant extent and that there still remain huge gaps between state CS education standards and the nationally recognized standard (produced by ACM). The tables in the appendix, adopted from the study done by CSTA, shows that on average only 55% of the ACM/CSTA model computer science education standards appear in the state standards for grades 9-12 across the
nation. There is a 70% average adoption for level I (K-8). For Level II there is a 35% adoption and for Level III there is only a 30% adoption (See appendix).

The scenario across different states is equally concerning. There are 16 states with no model curriculum standards adopted at Level II and 22 states with no model curriculum standards adopted at Level III. Table 1 in the appendix shows the percent of standards adopted by each state at each level. These rates are likely to get worse as states move to adopt the Common Core State Standards Initiative (CCSSI) which aims at adjusting state content standards for mathematics among other subjects. Many states have some computer science standards within the mathematics framework and CCSSI does not specifically mention computer science. As a consequence some states may drop some of the computer science standards within their state educational plans.

**Scenario of Teacher Training in Computer Science in Various States**

Another key factor contributing to the crisis of K12 CS education is lack of a consistent educational standard for teacher training. In most states, Computer Science is often taught by teachers who have little or no training in CS. The wide range of topics in CS and the continuous development in many of the CS topics make teaching extremely challenging for even most dedicated teachers. The certification for teaching CS, unfortunately, is either non-existent or severely disconnected from the discipline in most states of the US. Study has shown [9] that in most states there is no clear guideline about CS certification/endorsement requirements resulting in huge confusion among teachers. Another survey conducted by CSTA [8] concludes that very few states have developed distinct certification requirements for CS. While majority of states do understand the importance of CS education at secondary and middle school level, many states do not have a clear definition or understanding of computer science as a discipline of study. In many states computer science is integrated into mathematics or other sciences and fails to provide the required depth and range of knowledge. According to our research, only 14 states clearly describe the requirements for CS teacher certification or endorsement in the websites of the corresponding departments of education [11].

Among these 14 states, Texas seems to have the most clearly defined CS curriculum for K12 education as well as teacher certification requirements. Computer Science standards have long been included in K-12 academic curriculum in Texas. These standards are implemented in a series of courses at elementary to high school levels. At high school level, Texas provides a comprehensive framework of CS courses with an in-depth focus on algorithm, data structure, and aspects of object oriented programming. In order to achieve high excellence and maintain the standards in CS education at high school level, Texas has mandated CS teacher certification for teaching Computer Science. In order to teach Computer Science in Texas, teachers need to hold either the Computer Science 8-12 certificate or the Secondary Computer Information Systems, Grades 6-12 certificate. (The latter is no longer issued anymore) [12]. The certification requires a new teacher from any discipline to acquire significant college level computer science education. Newly issued certificates are valid for 5 years. A total of 78 credit hour course work (including 36 hours for CS) is required for this certification. CS courses encompass all fundamental areas of computer science including programming, algorithm design and data structures, computer organization and networking, security and applications such as web design. According to CSTA report [6,7], Texas has a well-defined CS curriculum with a rigorous teacher certification program and as a consequence Texas face fewer education related problems than other states.

**An Example Solution: CS Teaching Endorsement Initiative in Georgia**

The state of Georgia adopted a new computing pathway based on the ACM model curriculum for K-12 Computer Science in 2007. Students who take this pathway must take a number of rigorous computing courses including programming. The Georgia Professional Standards Commission (PSC) adopted a voluntary Secondary Computer Science Endorsement in December 2007. This endorsement can be added to any existing level 4 or higher secondary professional teaching certificate in a secondary or P-12 certification field. The program will enable
teachers to demonstrate in-depth knowledge of most important Computer Science topics including high level computer programming, system hardware and software, networking and history of computing. A teacher equipped with this endorsement will be able to teach Beginning Programming, Intermediate Programming, and Advanced Placement Computer Science AB. [13, 14]. Figure 1 (adopted from [6]) shows Georgia Computing Curriculum as compared to model curriculum set by ACM.

Figure 1: Comparison of Georgia computing curriculum with the ACM curriculum

Implementation of CS Teacher Endorsement Program by Columbus State University

Guided by the requirements for teacher endorsements established by the Georgia Professional, the TSYS School of Computer Science at Columbus State University implemented the first CS teachers’ endorsement program in Georgia [15]. The following steps were undertaken in order to meet the standards set forth by the PSC:

- Ensuring the programs aligned with the teacher preparation unit's Conceptual Framework
- Developing of the curriculum, including the specific courses within that curriculum
- Developing programs of study that detailed the recommended sequence of courses
- Developing transition points that could be used to assess student progress in the program
- Developing and/or identifying opportunities for student field experiences and clinical practice
- Developing and/or identifying assessments that would be used to measure student progress and provide evidence of meeting the PSC standards
- Soliciting professionals to serve on the advisory board
- Gathering faculty background information including vitas
- Participating in the program review

The endorsement program offers both undergraduate and graduate curriculum in Computer Science. Individuals already holding a clear renewable teaching certificate may apply for the graduate level endorsement program which consists of six courses including four graduate level CS courses and a practicum course in CS. All other individuals wishing to teach Computer Science may apply for the undergraduate endorsement program which
consists of eleven courses including eight CS courses and a practicum in CS. The tables below present the two curriculums.

### Table 1: Undergraduate Program of Study

<table>
<thead>
<tr>
<th>Year</th>
<th>Fall</th>
<th>Spring</th>
<th>Summer</th>
</tr>
</thead>
<tbody>
<tr>
<td>1(^{st}) Year:</td>
<td>Introduction to Information Technology</td>
<td>Computer Science 1</td>
<td>Computer Science 1 Lab</td>
</tr>
<tr>
<td>2(^{nd}) Year:</td>
<td>Computer Science 2</td>
<td>Data Structures</td>
<td></td>
</tr>
<tr>
<td>3(^{rd}) Year:</td>
<td>Computer Organization</td>
<td>Programming Languages</td>
<td>Computer Networks</td>
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<tr>
<td></td>
<td>Internet Programming</td>
<td></td>
<td></td>
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<tr>
<td>4(^{th}) Year:</td>
<td>Methods of Teaching Computer Science</td>
<td>Practicum in Computer Science</td>
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### Table 2: Graduate Program of Study, Fall Entry

<table>
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<tr>
<th>Year</th>
<th>Fall</th>
<th>Spring</th>
<th>Summer</th>
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<tbody>
<tr>
<td>1(^{st}) Year:</td>
<td>Fundamental Principles of Computer Science</td>
<td>Programming Languages</td>
<td>Computer Networks</td>
</tr>
<tr>
<td></td>
<td>Fundamentals of Computer Programming and Data Structures</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2(^{nd}) Year:</td>
<td>Methods of Teaching Computer Science</td>
<td>Practicum in Computer Science</td>
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### Table 3: Graduate Program of Study, Spring Entry

<table>
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<tr>
<th>Year</th>
<th>Fall</th>
<th>Spring</th>
<th>Summer</th>
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<tbody>
<tr>
<td>1(^{st}) Year:</td>
<td>Fundamental Principles of Computer Science</td>
<td>Methods of Teaching Computer Science</td>
<td>Programming Languages</td>
</tr>
<tr>
<td></td>
<td>Fundamentals of Computer Programming and Data Structures</td>
<td>Practicum in Computer Science</td>
<td></td>
</tr>
<tr>
<td>2(^{nd}) Year:</td>
<td>Methods of Teaching Computer Science</td>
<td>Practicum in Computer Science</td>
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An advisory board for this program was instituted in order to provide feedback on the program and to make recommendations for improving the curriculum. Several middle and high school teachers together with the director of the Career and Technical Education for the local school district were solicited and agreed to serve on the board. This board will meet two or three times each year to discuss the program and to make recommendations for improving it. During February 14-17, 2010, a three-member team representing the Professional Standards Commission conducted an electronic review of the undergraduate and graduate endorsement programs to determine if the proposed programs met or exceeded the following Georgia standards:

- Candidate knowledge skills and dispositions
- Content Knowledge for Teacher Candidates
- Pedagogical Content Knowledge for Teachers
- Pedagogical and Professional Knowledge and Skills for Teachers
- Student Learning for Teachers
- Professional Knowledge for Other School Professionals
The program received “Developmental Approval” by the Professional Standards Commission on May 13, 2010.

Conclusion

The decline in students interested in Computer Science over the last several decades may threaten the United States’ capability to compete in a world built around an ever increasing need for information technology and computing professionals. In this paper, the authors present a study on the current status of school level CS education and CS teacher certification requirements and show that despite of the national push most states have not adopted the national standard of CS curriculum at a significant level. Furthermore, teacher certification for CS is either non-existent or flawed and inadequate. The authors present their effort to possibly reverse this trend by implementing a Computer Science endorsement program for secondary school teachers. This endorsement program focuses on the national level model CS curriculum and meets the standards set by Georgia Professional Standards Commission. Steps are currently underway to market the program and to make it as widely available to prospective and in-service teachers as possible. Implementation of this online program will no doubt play a significant role in improving the standard of Computer Science teaching at schools for the foreseeable future.

Reference

Appendix:

The following table is adopted from reference [].

Table 1: State by State Adoption of Computer Science Standards by Level