Exploring Computer Science and a High School Program of Study in Computing

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Abstract - Starting from the Exploring Computer Science course, originally developed for high schools in Los Angeles, we have attacked the problem of spreading CS curricula into the high school level. In this paper we review the state of computing at the high school level; describe our project, the partnerships that make it possible, and the impact on students; then report the lessons learned and plans for developing a high school CS program of study beneficial to both students continuing to higher education and to those immediately entering the workforce.

Keywords: ECS, K-12, Pathway, Course Sequence.

1 Introduction

The Bureau of Labor Statistics predicts that computing will create more jobs between 2010 and 2020 than all other science and engineering fields combined [1]. Although undergraduate enrollments in computer science (CS) have increased in each of the past five years, including a 29% increase from 2011 to 2012 [2], only 30% of the 1.4 million jobs for computer specialists projected by 2020 are expected to be filled by U.S. computing graduates [3], and only 2% of ACT-tested 2012 high school graduates expressed a career interest in computer and information specialties [4].

The problems with high school CS curricula are well known. Since 2005, the number of high schools offering an introductory CS course decreased by 17% and those offering an Advanced Placement (AP) CS course decreased by 33% [5]. In 2012, only 2,978 of the more than 42,000 U.S. high schools offered the AP CS exam [6]. Between 2002 and 2012, while the number of students who took AP exams in all fields of math and science more than doubled, the number who took the AP exam in CS remained relatively unchanged [7].

In our own state of California, the dot-com bust of 2000 and news of off-shoring had a significant personal impact on many families and likely influenced students against pursuing a career in computing. While the total number of California high school students increased 20% from 2.48 to 2.98 million from academic year 1998-99 to 2008-09, enrollments in CS courses fell by 34% from 322 to 212 thousand [8] and made CS classes some of the first to go when the state’s education budgets were slashed. California now has one of the lowest CS AP participation rates in the nation; despite being a high-tech center for computing and the home of Silicon Valley, only 3,101 California high school students took the CS AP test in 2011 [9].

There’s a perfect storm building now around high school CS – both in California and across the nation. Even President Obama has said that he thinks “it makes sense” to have a computer programming language graduation requirement in high schools [10]. He stated that it is important for those students who will go to college as well as for those who plan to immediately enter the workforce. Several independent but related efforts have developed new CS courses that are now spreading throughout our nation’s high schools, creating opportunities to integrate these courses into an appropriate sequence referred to as a program of study.

1.1 Curriculum development efforts

In 2006, Jeannette Wing introduced her well-known article on Computational Thinking [11], which influenced Google’s creation of the Computer Science for High School (CS4HS) initiative to promote CS and Computational Thinking. The CS4HS project has now reached more than 1,800 teachers and 130,000 students in the United States alone [12]. More recently, the International Baccalaureate (IB) Program announced a revision of their CS courses, reducing the emphasis on Java programming and instead focusing on Computational Thinking [13]. In her role at the National Science Foundation (NSF), Jan Cuny has been leading the development of the CS10K project that seeks to have 10,000 well-trained CS teachers in 10,000 high schools across the United States by 2015 [14]. As part of that effort, two new high school CS courses have been developed to supplement the existing CS AP course: an introductory pre-AP course called “Exploring Computer Science” (ECS) and an intermediate course to be offered for AP credit called “Computer Science Principles” (CSP).

ECS was originally created “to increase and enhance the computer science learning opportunities in the Los Angeles Unified School District (LAUSD) and to broaden the participation of African-American, Latinos, and female students in learning computer science” [15]. Because of its success, ECS has now spread to more than 80 schools in five states [16]. To facilitate its adoption, SRI International recently released draft curriculum alignments of ECS to the California [17] and Illinois [18] state standards, including correlation to the Common Core Standards, the Next Generation Science Standards, the ISTE National Educational Technology Standards (NETS) and the K-12 Computer Science Standards developed by the Computer Science Teachers Association (CSTA). These curriculum alignments were prepared by one of our ECS teachers while working at
CSP was developed in conjunction with the College Board, which plans for the first AP test for CSP to be offered during the 2016-17 academic year. NSF-sponsored pilots of CSP have now been offered at 20 universities and high schools in 12 states [19]. Project Lead The Way (PLTW) will pilot its own version of CSP called “Computer Science and Software Engineering” (CSE) in 50 high schools in 2013-14, with plans to implement the course at more than 500 schools the following year [20].

In California, the Mid-Pacific Information and Communication Technologies Center (MPICT) is an NSF-funded effort aimed at improving ICT education in its region, which encompasses California, Nevada, Hawaii, and the Pacific Territories. While the emphasis of MPICT is on two-year community colleges, they also work with K-12 networks, other NSF-funded Centers (through the Advanced Technological Education Program), the California Community Colleges ICT Collaborative, four-year institutions, and industry employers to identify best practices, leverage and improve ICT education in the region to create a diverse technologically prepared workforce to meet the economic demands of the region. One of their goals is to identify student learning outcomes that may serve as the basis for educational pathways.

The Alliance for California Computing Education for Students and Schools (ACCESS)1 is a collaborative effort bringing together key stakeholders in CS education (K-12 administration, CS post-secondary education, schools of education, teacher training programs, industry, and both regional and national non-profits/policy organizations) to provide equitable access to high-quality K-16 CS education for all California students.

ConnectEd, the California Center for College and Career, is a partnership of several organizations focused on bringing a Linked Learning approach to California high schools. In this approach, students follow a multiyear sequence of integrated academic and Career Technical Education (CTE) courses organized around a broad theme, interest area, or industry sector. Used in schools throughout California, this approach has been shown to lead to higher graduation rates, increased postsecondary enrollments, higher earning potential, and greater civic engagement.

2 Our approach

Our project expanded the reach of ECS to Silicon Valley. Since the summer of 2010, we have been working to establish ECS as the foundation for a sequence of CS courses for students in San Jose area high schools. We began by identifying high-need districts and high schools, meeting with district superintendents, principals, counselors and teachers to obtain their support, and applying for funding from NSF. The following sections describe how we selected our partner districts and schools, how our NSF grants support our work, and the content and pedagogy of the ECS curriculum.

2.1 Selection of schools and districts

We chose to work with school districts that had a significant percentage of students who are under-represented in computing and are located in lower-income areas of San Jose. We selected schools from three different school districts - the East Side Union High School District (ESUHSD), the San Jose Unified School District (SJUSD), and the Santa Clara Unified School District (SCUSD). In each district, more than half of the students were neither white nor Asian, and 43% were enrolled in the free or reduced price meal program.

ESUHSD is one of California’s largest high school districts, with an enrollment of over 25,000 students in 22 high schools encompassing an area of 180 square miles. Fifty native languages are spoken by East Side students and there is a wide range of socioeconomic levels in the district. Five high schools in ESUHSD were selected for the project: Evergreen Valley, Independence, Oak Grove, Santa Teresa, and Silver Creek.

SJUSD covers the major portion of the city of San Jose, and a geographic area of over 100 square miles. As one of the largest urban school districts in California, SJUSD has 27 elementary schools, six middle schools and seven high schools. The District’s high school student population totals almost 10,000 students. Three high schools in SJUSD were selected: Pioneer, San Jose, and Willow Glen.

SCUSD serves over 14,700 K-12 students, and an additional 14,000 students in alternative programs offered from Preschool through Adult Education. Neighborhoods in the cities of Santa Clara, Sunnyvale and San Jose comprise the District’s 56 square-mile area. The District includes 16 elementary schools, one K-8 school, three middle schools, and two comprehensive high schools. Both high schools in SCUSD were selected: Santa Clara and Adrian Wilcox.

When we began our project in the summer of 2010, there were very few CS courses offered at our partner schools. When the principals were asked about CS courses that were available, many reported courses with titles such as “Computer Applications” (i.e., Microsoft Office), “Computer Fundamentals”, “Digital Electronics”, “Web Design”, “Multimedia”, “Technology Literature”, or “CAD Drafting”. Out of the ten schools, only two reported offering both an “Introduction to Computer Science” programming course and an AP CS course. A second school offered only the introductory course, and a third only the AP CS course. The equipment situation wasn’t much better: When asked to offer ECS, all but two of the schools said that they would need a

1 ACCESS was previously known as the California Computing Education Advocacy Network (CCEAN).
computer lab — either because they didn’t have one, or because it was already committed to other courses.

### 2.2 Funding and equipment

Our project has been supported by two NSF grants and a donation of 350 desktop computers from Santa Clara University (SCU) through its three-year replacement cycle of office and laboratory computers.

An initial grant from NSF’s Broadening Participation in Computing (BPC) program funded workshops for teachers on the ECS curriculum and pedagogy, and provided LEGO Mindstorm™ robotics kits and funds for administrative support in each of the schools. We held four weeks of summer professional development (PD) in 2010, three in 2011, and two in 2012, with some teachers attending more than one summer. Each summer PD was supplemented by three one-day follow-up PD sessions on Saturdays in the fall and a reflection workshop in the spring. To date, we have trained a total of 17 ECS teachers; of these, ten are teaching ECS in our partner schools, some have not yet taught ECS, some have retired or been reassigned to other courses, and two were from schools outside our partner districts.

A second grant from NSF’s Graduate STEM Fellows in K-12 Education (GK-12) program funded graduate engineering students to support the ECS teachers in their classrooms, and provided stipends to the teachers for helping to strengthen the organizational, leadership and presentation skills of the graduate students. We gave preference to graduate students who could serve as role models for students typically under-represented in computing. They each received a week of PD on the technical content of ECS and two days on classroom management, and were then assigned to two ECS class sections. They work in each ECS classroom twice a week and meet with the teachers after class to reflect and plan. They are expected to help prepare lesson plans, assignments and assessment instruments, to provide technical support to the teachers and students, and to prepare and give a minimum of six lectures in each classroom throughout the year.

### 2.3 Description of the ECS curriculum

The ECS curriculum is designed to engage high school students in computational thinking and make them aware of the importance of computing in a huge variety of disciplines and careers. The students learn about problem-solving, algorithm development, programming, and the use of computing applications in a variety of contexts that make sense in their lives. The curriculum also addresses the societal context and ethical issues that arise with the ubiquitous use of computers today.

As we believe was intended by the developers of the original ECS curriculum [21], we have modified some of the lessons to make them relevant to our population of students.

The specific computing tools and programming languages that are used in each unit are less important than the inclusive and engaging pedagogy that encourages students to make computational thinking concepts their “own.”

The pedagogy outlined in the curriculum is inquiry-based. It uses the “5 E Model” by R. Bybee [22], detailing strategies that enable the students to Engage, Explore, Explain, Elaborate, and finally Evaluate their own progress and developing expertise in each of the topics. The students learn to analyze problems, ask questions, work in teams, reflect on their own thinking processes and communicate such, and to be creative in their quest for solutions to problems or projects in which they have a personal interest.

The year-long course consists of six modules: Human Computer Interaction, Problem Solving, Web Design, Introduction to Programming, Computing and Data Analysis, and Robotics. While the teachers at each school have some flexibility in organizing their own classes and the time spent on each unit, we expect that they all cover each of the units. To help engage the students in mastering these topics we’ve introduced a contest at the end of the academic year, with awards for entries in each of the units on Web Design, Programming, Data Analysis, and Robotics. Within each school, students compete to represent their school as finalists in the project-wide competition held on the SCU campus in May.

### 3 Results and lessons learned

Our success with ECS has only been possible because of partnerships throughout the K-12 community. Besides the teachers who taught the ECS curriculum, we could not have succeeded without the district superintendents who endorsed the project and were instrumental in the selection of our partner schools, curriculum coordinators who pursued approval for ECS to count towards the University of California admission requirements as a “g” elective and helped to navigate course prerequisite and scheduling constraints, principals who supported the ECS teachers and encouraged the development of new course sequences, and counselors who helped recruit students into the ECS courses.

After a modest start, our partner schools are now experiencing increased student demand for ECS. Many schools have added additional sections, with at least one reporting that they could fill as many sections as they are able to offer. The ECS course is currently running in nine of these schools, with 365 students enrolled in a total of 14 sections. Since the project began, 30 sections of ECS have been taught to more than 785 students.

#### 3.1 Student demographics

Unfortunately, while we are offering the courses in schools with a high percentage of underrepresented students, we have yet to match the demographics of the schools with
the enrollment in the ECS course. The majority of the students enrolled in ECS is male and not of ethnicities considered to be under-represented in STEM. In the current year, 55% of the ECS students identified themselves as either Caucasian or Asian, and only 21% of the students are female. We are attempting to increase the number of under-represented students through recruitment efforts mentioned in section 3.3, below.

### 3.2 Use of graduate students

The graduate students have been an asset much appreciated by the high school teachers and students. Initially (2011-12 academic year), the graduate students were only used as helpers in most of the high school classrooms, although exceptions in which the graduate student taught several classes did occur. For the 2012-13 academic year, we have provided more specific guidance on the use of the graduate students in order to ensure that they are developing communication skills and sharing more of their own work with the students, as well as providing deeper expertise in the subject matter of the course in the classrooms.

The following comments are representative of the feedback that we received from students and teachers about the added benefit of having the graduate students in the classrooms:

**ECS Teacher:** “I feel less on my own having the graduate student to help. I feel like I have support. Just having anyone knowledgeable to talk to is a great help. This makes me more confident about giving assignments to the students.”

**High School Student:** “My positive attitude towards computer science has increased, especially that [the graduate student] has talked about not only the skills you need, but also the attitude you need (like patience) when it comes to computer science. He made us realize that going to college and learning about this will be fun, but at the same time, not everything is easy, and patience is a must because some activities take a LONG time to accomplish.”

The graduate assistants have expressed an appreciation for the impact they have as role models and mentors to the high school students:

**Graduate Assistant:** “I think the students are impressed that someone like me is in engineering and knows the material as well as the teacher. This gives them confidence and motivation. In addition, the only female student in one class is motivated to continue in engineering, as I am also a female, and sees that I have made it as well.”

### 3.3 Student recruitment

We have increased our efforts at recruitment, paying closer attention to the timing for fall registration choices in each high school, and having undergraduate students give presentations to high school students about the various career paths in computing. We believe that these efforts, and word of mouth among the students, have contributed to the 33% increase of ECS enrollments from 2011-12 to 2012-13. However, we still find that it is difficult to get the right mix of students enrolled in the classes, and need to improve our efforts to recruit the most underrepresented students. To this end we have supplied materials to the guidance counselors within each school, ensuring that they are aware of the benefits of learning about computing, and encouraging them to recommend the course to students currently underrepresented in the course at their school.

### 3.4 Teacher certification issues

California, like most states, does not offer teacher certification in CS. Instead, who is allowed to teach ECS is determined by whether each school district classifies the course as either primarily academic or vocational. If a CS course is not a CTE course, the teacher must either hold a credential in business, mathematics or industrial technology education (ITE), or a supplementary authorization in computer concepts and applications. However, if ECS were considered to be primarily vocational, then it could be taught by a CTE teacher. All of the teachers in our partner schools hold a credential in math.

### 3.5 How does ECS fit student graduation needs?

In California, students who plan to continue on to college are guided in their choice of courses by the University of California’s (UC) “A through G” admission requirements. Neither the UC requirements nor the high school graduation requirements include a course in CS. The ECS course has been approved by UC to satisfy the one year of coursework required from their “G-elective” category, but ECS competes within this category with a large number of other courses. (UC does require two, and recommends three, years of coursework in their “D-laboratory science” category, but historically this has been restricted to courses in the natural sciences, such as biology, chemistry and physics.) The ECS course also qualifies for CTE credit, which is useful for those students planning to enter the workforce directly after high school.

In order to make it clear how the ECS course can fit into both academic and career plans, we are currently cooperating in the effort to create a “Pathway” or sequence of computing courses, described in the next section.

### 3.6 How does ECS fit within schools’ existing curricula offerings?

With budgets as they are, in California as well as elsewhere, schools cannot add new courses just because it seems like a good idea for the students. Some schools already have courses in “computing” – these courses can be from a
wide variety of offerings such as keyboarding, using document editing tools, spreadsheets, photo editing tools, robotics, or programming classes. All of these and the ECS course are electives, and thus are the first to be eliminated in favor of required courses when budgets are reduced. A solid case needs to be made if the school is to replace a current offering, or add another course that complements it.

4 Next steps

The introduction of ECS into San Jose area high schools has been enthusiastically received by students, teachers, and administration. Students are asking what they can take next in computing, teachers are excited by the level of student interest, and school and district officials have started to think about how best to develop appropriate and coherent CS sequences for both CTE and college bound students.

4.1 Developing a CS Program of Study

A “Program of Study” is a prescribed multi-year sequence of courses to prepare students for advanced study or a career in a particular discipline. A typical high school sequence would consist of three or four courses from the specific discipline that include a number of required foundation courses and a possible set of electives.

ECS has proven to be a successful and stable curriculum, and has been recommended by ACCESS to be the first foundation course in any CS Program of Study. However, ECS would be insufficient as the only prerequisite for the existing AP CS course and Programs of Study that include the latter will need an intermediate level course such as CSP. A standard CSP curriculum, however, is likely to continue evolving until the 2016-17 introduction of its AP exam. Thus although CSP may ultimately become the pertinent second foundation requirement, schools that want to establish a Program of Study may now effectively use an introductory programming course as a temporary alternative.

A Program of Study for students who intend to pursue advanced study in CS should include the existing AP CS course, possibly followed by a fourth (elective) course such as Web Design, Database Systems, Networking, or System Administration. A Program of Study for CTE students might appropriately replace AP CS by a second elective.

4.2 Sustaining a CS curriculum

Once our NSF project is over, the continued success of ECS and any Programs of Study in CS requires that the K-12 community take ownership of curriculum development, training and support. As a first step, this summer we will be training some of our current ECS teachers to become teacher-trainers in a new ECS workshop to be held at the Santa Clara County Office of Education (SCCOE). Statewide interest in ECS is high, as evidenced by the fact that within a week of opening registration, 30 teachers from outside our partner districts had registered for the first SCCOE workshop to be held this August.

5 Conclusions

This is a critical time for high school CS. The ECS and CSP courses have been enthusiastically adopted at several schools across the nation, and there is a renewed interest among school administrators to expand their course offerings in CS. We have described how these courses form the foundation of a high school Program of Study in CS and our efforts to move to a sustainable model in which the K-12 community takes ownership of CS curriculum development and support.

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7 References


[8] Lloyd McCabe, CA Dept. of Ed., Compiled from Data Quest data.


