TRAINING A DIVERSE COMPUTER SCIENCE TEACHER POPULATION

Bradley Beth, Calvin Lin, and George Veletsianos

The CS10K project has the ambitious goal of dramatically expanding the pool of qualified high school computer science (CS) teachers. We offer three recommendations for accomplishing this goal, basing our recommendations on five years of experience in training teachers to offer a dual enrollment[1] CS Principles course. We recommend: (1) that when selecting and training teachers, focus on teacher strengths rather than weaknesses; (2) that in order to achieve scale and to promote best practices, create a hierarchical support system; and (3) that courses be designed with an explicit focus on the high school classroom environment.

Thriving in Our Digital World

Thriving in Our Digital World is a Computer Science Principles (CSP) course designed through a collaboration between the Department of Computer Science and the College of Education at the University of Texas at Austin and the School of Education and Technology at Royal Roads University.[2] As part of the CSP umbrella, the course focuses on broadening participation in computing among all high school students, including those underrepresented in traditional computer science classes [7]. We designed the course from the ground up to incorporate evidence-based pedagogies and innovations shown to encourage participation and success broadly among underrepresented populations of students. These include (1) project-based learning (PBL), (2) scaffolding and collaboration, (3) a blended learning delivery model, (4) an interdisciplinary focus on content, and (5) a dual enrollment framework [1,6,9,11]. Since one goal of the course was to increase participation of underrepresented groups in CS, it is worth noting its comparative success (Table 1). To date, *Thriving in Our Digital World*, has enrolled a more diverse group of students than the existing Advanced Placement® (AP®) Computer Science A course. We provide the state of Texas whole population characteristics for comparison.

TABLE 1. DEMOGRAPHIC COMPARISON OF UNDERREPRESENTED GROUPS (2012–2015)[3]

	Thriving in Our Digital World	AP Computer Science A Texas	AP Computer Science A U.S.	State of Texas whole population
Female	30.3%	23.5%	19.2%	50.4%
Black	6.7%	3.6%	3.9%	11.8%
Hispanic	32.9%	19.2%	8.3%	37.6%

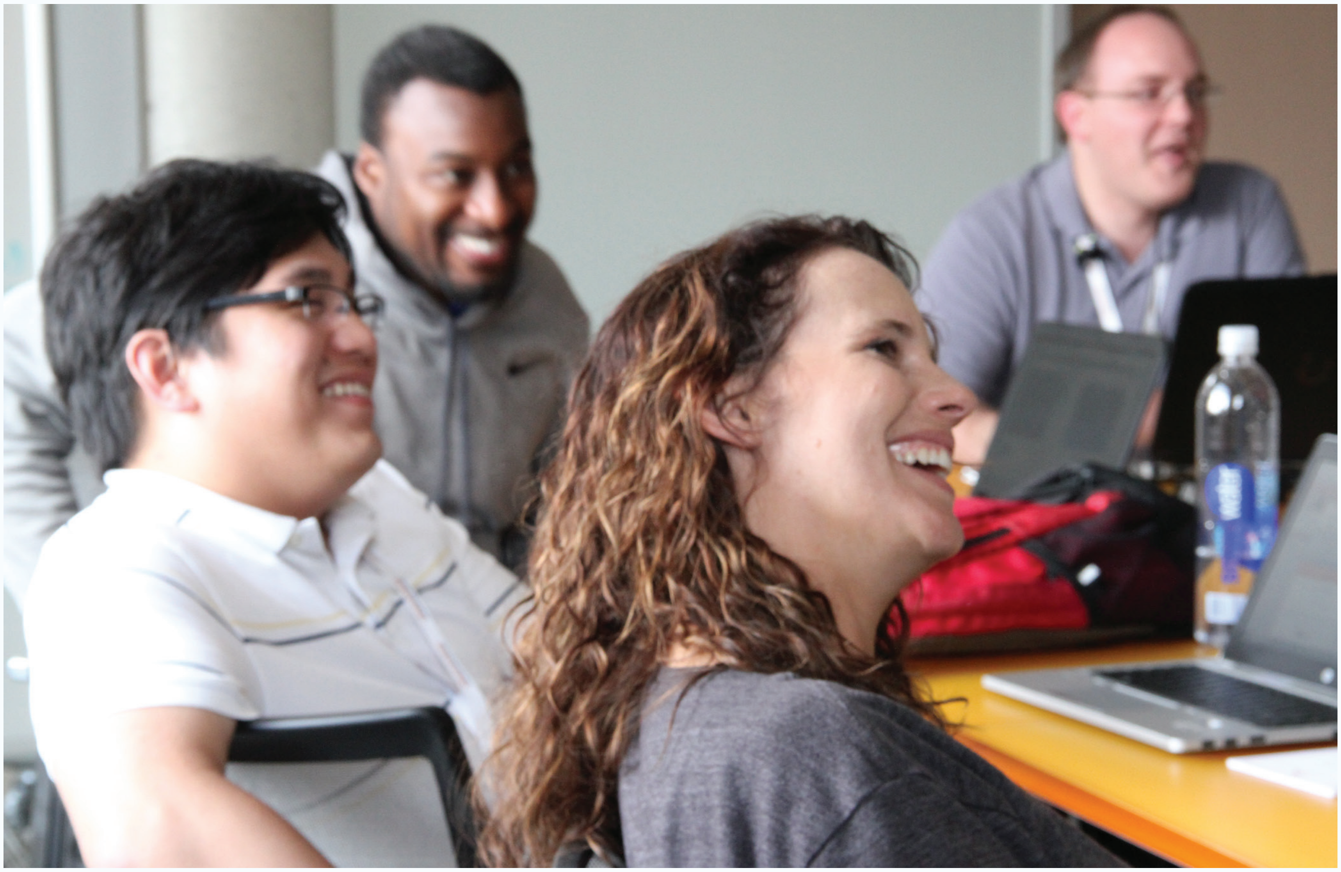
Modular units comprise the course content, each focusing on a particular application of computer science—the global impact of computing, programming, digital representation, digital manipulation of media, Big Data, and artificial intelligence. Students learn about each of these topics by creating end-of-module project artifacts. Throughout the course, we emphasize both computational thinking practices and college readiness behaviors.

The dual enrollment model has been particularly useful in informing revisions of the course and in training teachers to teach it. Teacher training begins with a nine-day intensive course model. Such models have been shown to be effective in similar initiatives aiming to improve the skills of computer science teachers, such as those in the United Kingdom described in [10]. Unlike other professional development models, however, we maintain regular contact with teachers over the course of the school year, viewing the course as a partnership. Teachers facilitate classroom instruction

1 OnRamps is a pioneering dual-enrollment program coordinated by The University of Texas at Austin that provides a University of Texas at Austin quality experience for high school and community college students throughout the state of Texas. See, for example, [11].

2 NSF Grant DRL-1441009, NSF Grant CNS-1138506, and by the University of Texas at Austin's OnRamps college readiness program have provided support for *Thriving in Our Digital World.*

3 Ericson offers data for Advanced Placement participation [4]. The United States Census Bureau provides Texas state demographic data [10].



using the materials supplied to them and provide formative assessment to refine the course, while project faculty and staff design/revise course content, activities, and scaffolds, provide ongoing teacher feedback, and score summative assessments for the companion university course.

Thriving in Our Digital World is entering its fourth year of implementation. To date twenty-one high schools throughout the state of Texas have offered the course, enabling us to gain an in-depth understanding of professional development, teacher preparation, and the need to provide on-demand support to the teachers who offer the course. The following characteristics have guided our course design and revision.

1. *Faithful implementation is important for valid assessment.* Because university staff directly assess student work while relying on classroom teachers to teach content and facilitate student understanding, it is critical that content coverage and classroom pacing be consistent with university expectations.
2. *Common assessments and rubrics are important for reliability across teachers.* Each student's college grade consists of online exams (40%) and projects graded by high school teachers (60%). Thus, our professional development and on-going support focus heavily on the use of common rubrics and assessment techniques.
3. *An ongoing university-school partnership is integral to the success of the project.* The success of this project depends on a partnership between schools (teachers, principals, superintendents) and university (staff, faculty, researchers). Unlike a traditional model where teachers attend a professional development session with little follow-up, the close interaction between teachers and university staff greatly informs the revision of both course content and professional development.

Recommendations

Our close relationship with our K–12 partners has allowed us to monitor and assess indicators of success among teachers, yielding three recommendations to those who design CSP courses and their professional development programs.

When selecting and training teachers, focus on their strengths.

Many skills are required to teach *Thriving in Our Digital World*. Rather than expect all teachers to have all of these skills, we look for strength in one or more of the following areas:

- *CS content knowledge.* While many of our most effective teachers have previously taught computer science, this background is neither necessary nor sufficient for success in teaching our course. For instance, we find that most experienced computer science teachers benefit greatly from exposure to a variety of learner-centered pedagogies and other instructional methods not commonly used in computer science classrooms. Beyond this, a unilateral focus on content knowledge may alienate many teachers. Ni and Guzdial [8] report that many

K–12 teachers teaching computer science courses do not strongly identify as computer science teachers.

- *Pedagogical Knowledge.* Teachers with experience in inquiry-based pedagogies add tremendous value to our professional development. In particular, experience with PBL is helpful in teaching our heavily scaffolded course. Much of our professional development is delivered in an inquiry-based active learning format [5], with teachers experiencing the project-based curriculum as students, so the presence of teachers with expertise in PBL greatly contributes to a positive group experience during professional development.
- *Facility with a variety of assessment and delivery techniques.* In addition to PBL, *Thriving in Our Digital World* uses a vast array of daily collaborations, discussions, open-ended projects, assigned readings, and writing prompts. Many of these approaches to learning are not typical in high school computer science course. We have found that experience with these methods of instruction is critical for successfully teaching the course—teachers from the humanities or social sciences backgrounds tend to be strongest in this area.

Thus, we advise the CS education community to recruit teachers with a diverse set of strengths—not just those with computer science content expertise. Such an effort will both grow the pool of potential teachers and improve the quality of the overall CSP teaching community.

Leverage the community to decentralize and strengthen teacher support.
If the CSP teacher community is to benefit from diverse perspectives and skills, then we need to foster communication among its members. Unfortunately, computer science teachers often feel isolated [3]. Our solution has been to help develop a community of teachers who can support one another. We encourage them to develop relationships as part of our professional development offerings so that they can later communicate and coordinate with colleagues who have similar problems and goals when they need to do so.

A thriving teacher community may be the single most important step in achieving long-term sustainability for the course, as the dual enrollment nature of our project makes it difficult to support vast numbers of teachers. In particular, our experience reveals two benefits of establishing a cohesive community:

1. *A centralized support system is resource prohibitive.* To maintain close relationships between teachers and staff, we limit the number of students and teachers that we can support (roughly twenty-five teachers at a time). One way to support a larger number of students and teachers is to partner them with experienced teachers who may be able to engage in peer mentoring and peer support.
2. *A spectrum of support is best.* Our experience suggests that different issues—from intent (curriculum design issues) to implementation (classroom issues)—are best handled by different sources of support. The work of Thompson and Bell [12] corroborates this finding—they found that computer science teachers in New Zealand rely on a variety of modalities for professional development, both formal and informal. We find that centralized support is better suited to clarifications of curricular issues, whereas distributed peer support is better suited for implementation issues (see Table 2).

We encourage [teachers] to develop relationships as part of our professional development offerings so that they can later communicate and coordinate with colleagues who have similar problems and goals when they need to do so.

We have found that clarification regarding pacing—such as thoroughly addressing loops prior to processing lists—is best addressed by course designers. On the other hand, resource questions—such as dealing with district firewalls—are often best addressed by peer teachers.

TABLE 2. THE BEST TEACHER SUPPORT DEPENDS ON CONTEXT

Centralized support	*Clarifications:* lesson intent, learning objectives, scope and sequence
↕	*Updates/Additions:* errata, supplementary activities, revisions
	Best Practices: differentiation, classroom strategies, misconceptions
Peer support	*Workarounds:* resource limitations, community-specific needs

Develop a curriculum explicitly for high school classrooms.
While both dual enrollment and Advanced Placement (AP) models aim to bring college-level coursework to high school settings, we strongly urge designers and other stakeholders to design high school courses with the high school environment in mind. In particular, implementation details should follow the constraints of the public K–12 school environment, as opposed to those of the university environment. We have established two heuristics to guide our work.

1. *Design for a high school environment.* The first major decision in the design of our course was whether we should retrofit an existing college course, which brings two advantages: (1) it minimizes effort by reusing material, and (2) it initiates the design process with complete alignment to the college curriculum. However, the companion college course at the University of Texas at Austin was not designed to be taught by high school teachers or to high school students. It was a course designed and taught by expert CS faculty to undergraduates at a flagship state university. In other words, it was designed for a different audience. Because a major goal of the project was to broaden participation in CS, the high school course needed to be engaging, relevant, and meaningful to high school students—features of instruction that were not considered in the development of the existing college course.

[W]e strongly urge designers and other stakeholders to design high school courses with the high school environment in mind.

2. *Question assumptions.* Implicit in the design of a college course are assumptions that do not necessarily translate to a high school classroom:
   a. *Material components.* Access to required materials and software varies greatly from campus to campus. In many cases, the ratio of students to computers in a high school environment would seem prohibitively restrictive to college instructors. Software installation permissions on high school student and teacher computers are often limited, and district-imposed firewall restrictions may render it impossible to access external resources.
   b. *Lab time.* In a college environment, faculty often assume that students have unrestricted access, specifically outside of class, to computing resources. Yet for many high school students—particularly those we are trying to reach—such access is simply infeasible. Therefore, the scope and sequence of daily classwork must include lab time.
   c. *Pacing.* While college courses generally complete in one semester, high school courses typically span two semesters. The effective use of this time requires more than simply adjusting the same activities to fit a longer timeframe. Given other constraints, particularly lab time, adjusting the pacing to match a high school environment requires thoughtful planning.

Final thoughts

Our experience in offering the *Thriving in Our Digital World* dual enrollment course has informed much of our approach in working with high school teachers and students. As the AP Computer Science Principles exam launch in the 2016–17 school year approaches, we are partnering with the UTeach Institute[4] to scale our course to reach many more students. While this large-scale effort moves away from the dual enrollment model, our initial offerings have greatly informed our approach as we design for sustainability. We have learned much in our one-on-one and one-to-many interactions with our partner teachers, and we hope to continue to build-upon their valuable experiences and feedback for years to come. For more information about both the dual enrollment and AP implementations of *Thriving in Our Digital World*, visit http://www.cs.utexas.edu/~engage/. **Ir**

[4] The UTeach Institute is the organization charged with ensuring the fidelity of implementation of the national UTeach STEM teacher preparation model and the expansion and sustainability of related STEM education innovations.

References

[1] Ash, K. "Blended learning models generating lessons learned." *Education Week*, 32, 9 (2012): s4–s5.
[2] Astrachan, O., et al. "The CS10K project: mobilizing the community to transform high school computing." In *Proceedings of the 42nd ACM Technical Symposium on Computer Science Education* (ACM, 2011):85.
[3] Center for Elementary Mathematics and Science Education. "Building an Operating System for Computer Science Education: Landscape Study." (The University of Chicago, 2013); http://outlier.uchicago.edu/computerscience/OS4CS/landscapestudy/. Accessed 2015 August 1.
[4] Ericson, B. "Detail Race and Gender Information 2014;" http://home.cc.gatech.edu/ice-gt/590. Accessed 2015 August 1.
[5] Garet, M.S., et al. "What makes professional development effective? Results from a national sample of teachers." *American Educational Research Journal*, 38, 4 (2001): 915–945.
[6] Hixson, N.K., Ravitz, J., and Whisman, A. *Extended Professional Development in Project-Based Learning: Impacts on 21st Century Teaching and Student Achievement.* (Charleston, WV, West Virginia Department of Education, Division of Teaching and Learning, Office of Research, 2012).
[7] National Science Foundation. "Award #0938336 - Using Computational Thinking to Model a New Course: Advanced Placement Computer Science: Principles;" http://www.nsf.gov/awardsearch/showAward. do?AwardNumber=0938336, 2009. Accessed 2015 August 1.
[8] Ni, L. and Guzdial, M. "Who AM I?: understanding high school computer science teachers' professional identity." In *Proceedings of the 43rd ACM technical symposium on Computer Science Education.* (ACM, 2012):499–504.
[9] Paul, J. "Living in a computing world: a step towards making knowledge of computing accessible to every student." *ACM Inroads*, 3, 2 (2012): 78–81.

BRADLEY BETH AND CALVIN LIN
Dept. of Computer Science
The University of Texas at Austin
Austin, Texas USA
http://www.cs.utexas.edu/~engage/

GEORGE VELETSIANOS
School of Education and Technology
Royal Roads University
Victoria, BC Canada
veletsianos@gmail.com

DOI: 10.1145/2829978