Integrating Computer Science Teacher Certification into a Secondary Mathematics Teacher Preparation Program: The Highlights

Jeremy Zelkowski, Becky Odom-Bartel, & Jeff Gray
The University of Alabama

Nationally, over the last two decades the mathematics and science teacher candidate (TC) pool has shrunk, creating massive shortages for filling classrooms with certified STEM teachers (Partelow, 2019). At the same time, computer science (CS) course offerings have increased in demand at the high school and even middle school level, growing exponentially (Klein, 2021). Since 2000, CS teachers have ultimately been inservice teachers of various disciplines, who have had to attend professional development to attempt to meet the CS teaching demands (Ahmad, 2017). In 2019, the Alabama legislature passed HB216 requiring that high schools, middle schools, and even elementary schools all offer CS courses by the 2022-2023 school year in response to the governor's focus on advancing STEM in Alabama. This progress legislation has the consequence of placing additional strains on the certified pool of STEM teachers. In response to the need for all schools to have a credentialed CS teacher in Alabama without sacrificing the preservice pool of secondary STEM TCs, we developed a partnership. This partnership at The University of Alabama (UA) has focused on developing a single CS 104 course (CS Principles, see below) to meet the mathematics major requirement of a CS course. CS 104 became the primary and desired option for secondary mathematics TCs as they saw the course as much more relevant than a pure CS-major introductory programming course. Two optional pathways were ultimately developed, leading mathematics TCs to dual certification in mathematics and CS. The effort has expanded further to a statewide partnership of six universities providing TCs of all secondary teaching disciplines the opportunity to be dually certified in their main teaching discipline with a CS add-on credential. We briefly describe our pathway models of integrating CS teacher preparation into secondary mathematics, as well as our statewide expansion and partnership with five other teacher preparation universities.

Conceptualizing and Building the Partnership

In 2013, we began discussions about enrolling mathematics TCs in Computer Science Principles (CSP) rather than an introductory CS programming course for CS majors. Mathematics TCs are required as part of their content major to complete an ancillary CS course. By 2015, CSP became an option and more than 90% of mathematics TCs completed CSP as the CS requirement. This initial collaborative partnership aligned with the National Science Foundation's (NSF) (2016) CSforALL Research-Practitioner Partnership call that led to a funded project to dually certify mathematics TCs with an add-on CS credential through an integrated and sequenced CS curriculum in the mathematics teacher preparation program (see pathway courses below). Our NSF-sponsored partnership developed two pathways for TCs to add-on a CS teaching endorsement. First, an Advanced Placement CSP course permit can be earned by successfully completing two CS sequenced courses. TCs had the option to complete an AP CSP summer institute upon graduation. Second, TCs can elect to move to a set of modules to prepare for the CS Praxis II for an add-on full CS subject teaching permit.

Certification Pathway Courses

We briefly describe our course pathway(s) developed within this collaborative work. The first pathway option is the two-course sequence (CS 104 → CS 49X/59X[1]) leading to a single course teaching permit. The second pathway option adds a third experience to the sequence focused on CS content knowledge to prepare for the CS Praxis II.

CS 104: Computer Science Principles

The first course introduces the core principles of CS from a broad spectrum of topics through an exploration of the *Big Ideas of Computing* (e.g., programming with a blocks-based language, discussion of computational concepts, explaining Internet protocols, and how principles of computing can be applied to solve general problems). In this course, students examine computing and its relation to creativity, abstraction, algorithms, programming, Big Data, Internet/networking, and societal impact. This course is modeled after the College Board's AP CSP curriculum. The purpose of this course is to introduce TCs as a student of CSP with the foundational content areas needed to begin their preparation as a CS educator in our path sequence.

CS 491, 492, 591, or 592: Computer Science Principles Curriculum

Building upon the concepts from CS 104, students explore in-depth an examination of the AP CSP curriculum from the CS 104 course, and how CS education is presented in the secondary education context. Students explore the current AP CSP and other CS curricula while developing resources for future teaching with a specific emphasis on the College Board's AP CSP curriculum. In CS 104, TCs learn the core AP CSP content and in CS 49X/59X they learn about the reason why the curriculum is structured to support diversity, equity, and inclusion (DEI). In CS 49X/59X students begin the course with an examination of the literature on current strategies for DEI and then use that literature and accompanying discussions to analyze current teaching methods for AP CSP and how they can be developed to meet these strategies. TC's debate latest data points on demographics when related to enrolled AP CSP students. These data points allow for discussion and awareness of the need to develop recruitment and exposure techniques that would greatly benefit marginalized communities in CS. Through readings, cooperative learning activities, coding practice, and lesson plan development, TCs develop a robust portfolio and confidence for teaching AP CSP with new pedagogical content knowledge.

CS Praxis II: Modules Preparation Course

The third experience in the summer is our CS pathway to prepare TCs for the Praxis 5652 CS exam who want more than just the CSP course teaching permit. Using multiple online tools and a virtual learning management system, students examine the five main

[1] CS 491, 492, 591, or 592: The courses are identical and depends on whether TCs are being certified at the baccalaureate level or post-bac level through face to face or online courses. Post-bac TCs complete some individual projects for a higher demand than undergraduates.

topics included in the 5652 exam: 1) impact of computing, 2) algorithmic and computational thinking, 3) programming, 4) data, and 5) computing systems and networking. This portion of the pathway uses a hybrid synchronous/asynchronous course instructional method to create and maintain a supportive community and cohort among the participants. The course includes two university facilitators (authors 2 and 3) who provide synchronous discussion opportunities throughout the 6-week immersive prep course. The interest, engagement, and growth of the TCs who completed the first two CS courses, and then prepped for the CS Praxis II, produced high levels of success leading to a larger project.

Prior Results Lead to a New Project Partnership: A Statewide Expansion

Alabama's HB216 provided preservice programs the ability and flexibility to "add-on" a CS teaching credential to any approved teacher education program. Our initial NSF pilot grant project led to 30 mathematics TCs at UA completing the two-course sequence (CS 104 to CS 49X/59X), contributing to TC eligibility for an AP CSP course-permit add-on credential when they finished their secondary mathematics program. Of the 30 TCs, 26 completed the secondary mathematics program and were eligible for the AP CSP add-on endorsement. Of the 26 TCs, 15 elected to advance to the third experience, the Praxis II prep course, with 14 TCs passing the CS Praxis II. The lone TC who did not pass did not complete the all the prep modules. More astoundingly, the 15 mathematics TCs scored on average 10 points higher (about 1.5 standard deviations) than Alabama inservice teachers on the Praxis II who participated in similar state provided CS professional development program before completing the same set of Praxis modules through UA. We believe the strength of the two-semester sequenced courses explains this 10-point difference. We suggest that the full two-course sequence offers a stronger content knowledge alternative to the 1-week of summer training that is typical of CS professional development for inservice teachers (Gray et al., 2020; Odom-Bartel et al., 2020, 2021; Zelkowski et al., 2022).

The success of our first NSF project led to a second NSF CSforALL statewide partnership with five other universities to open the CS pathway to all secondary teaching disciplines for TCs.[2] The new NSF project established partnerships with colleagues throughout Alabama from Jacksonville State University, Alabama State University, South Alabama University, as well as the University of Alabama (UA) system (UA Birmingham, UA Huntsville). Our efforts made a concerted effort to provide online and summer options for up to 90 secondary TCs from multiple institutions that would not impede their ability to complete their existing teacher education program at their home institution. The first cohort of our multi-institutional effort enrolled in the first course spring semester 2022 and included 28 TCs from secondary mathematics, science, English, social studies, and physical education from the six universities.

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Conclusion

What began with a brief 2013 hallway conversation between faculty members from different colleges (authors 1 and 3) led to a statewide partnership across six universities to provide secondary TCs the ability to meet state demands for teaching CS in K-12 schools. Moreover, the pilot project produced a statewide early career teacher leader in Alabama. A 2018 graduate from the first UA cohort presented at AMTE in 2019 with author 1, and in 2021, she led the statewide professional development training of inservice teachers at various AP CSP workshops (see Figure 1).

Figure 1. A Program Graduate Leading Statewide Professional Development for CSP

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For mathematics teacher educators, our message in this brief article is to consider the ever-changing and high demand needs of CS growth. We believe that CS can play an important role in the teaching and learning of mathematics, for example using the Bootstrap Algebra curriculum (https://bootstrapworld.org/materials/algebra/). Through our field's modeling, problem solving, and data science/analysis standards, the ability to integrate CS as a medium into preparation programs and the K-12 mathematics curriculum will continue to increase in the future years (Fisler et al., 2021). Developing STEM teachers' readiness and expertise in CS content knowledge and pedagogical content knowledge was our goal. We recommend looking more deeply at our program design and ability to integrate CS into secondary mathematics teacher preparation (Gray et al., 2020; Odom-Bartel et al., 2020, 2021; Zelkowski et al., 2022) as a way to improve equitable learning and career opportunities through mathematics and computer science for all students. We believe the integration of ideas from CS into the teaching of some mathematics topics and vice-versa, provide students opportunities to engage with

integrated STEM activities rather than in isolated subject classrooms in schools. We further believe that high school graduation requirements in mathematics should have the potential to consider a quality CS and mathematics infused course in lieu of say Algebra-2 (Zelkowski, 2008, 2010, 2011). A mathematics teacher well-trained in the teaching of mathematics and computer science ultimately can supplement important ideas of Algebra-2 into a CSP curriculum or vice-versa (Fisler et al., 2021). We ask the important question for the field to consider in relation to state policies as to whether "students" best interest is considered for life/career/college. Do all students benefit from Algebra-2 in high school or would an AP CSP course, an infused CS and mathematics course, or an infused mathematics CS course serve as a stronger opportunity in life/career/college for some students?

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