Assessing the Statewide Impact of K-12 Computer Science Pathways: Increasing Teacher Preparation and Expanding Student Computational Literacy
Education Innovation and Research Program - Early Phase Grant

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A. Introduction and Response to Absolute Priorities

A.1. National Significance of the Proposed Project

Many of the most in-demand career pathways require Computer Science (CS)-related skills (Clifford, 2017), including 3 of the top 6 occupations in Alabama (Alabama Jobs, 2017). Low participation and interest in CS careers, particularly among students from rural areas, is often attributed to the lack of "preparatory privilege" (Margolis et al., 2008), encompassing unavailability of resources and experiences that build content knowledge and related skills (e.g., college preparatory courses, such as Advanced Placement classes), and access to role models (e.g., mentors and industry professionals). The impact of the lack of preparatory privilege extends beyond academic proficiency; a school community composed of teachers and counselors who are unaware of details about in-demand careers are often not able to support emerging social identities that promote interest and persistence in CS and other STEM areas (Kozoll and Osborne, 2004). The problem is particularly acute for rural communities that have a high number of students from underrepresented minorities, such as residents of the "Alabama Black Belt." With African Americans comprising less than 5% of the jobs at the most popular software companies, and African American females occupying less than 1% of those positions (Dillon et al., 2015), it is imperative that a more diverse CS and STEM workforce emerges from among students in rural communities with high underrepresentation. The Alabama State Department of Education (ALSDE) proposes an **Early Phase** project, *Pathways for Alabama Computer Science* (PACS), to address EIR **Absolute Priorities 1** and **3**, along with the **Competitive Preference Priority**. PACS initiates a high school pathway of CS courses, primarily for high-need schools (defined as Title 1) in rural areas (defined by locale code).

The interest in CS has seen a dramatic spike in K-12 schools, as evidenced by a recent Gallup/Google poll documenting the desire for CS classes by students and parents (Gallup, 2016). Although CS figures prominently as a career option, recent reports (Century et al., 2015) reveal that the sector is poorly diversified. Extending these two observations, there are several factors that underscore the motivation and rationale of PACS: 1) an existing virtual online CS course available to all Alabama high schools has 82% of enrollment comprised of white males; to reach rural students with diverse backgrounds, a CS course must be brought locally to rural schools - online virtual CS courses are not reaching rural underrepresented students; 2) a pathway of courses is needed to initiate and retain interest while strengthening CS content knowledge (beginning with a CS-infused Algebra course taken by many students in each school, followed by a sequence of evidence-based CS courses); 3) students in rural areas are aided by preparatory experiences and additional academic year activities beyond the classroom (Gay, 2010); 4) counselors from rural schools benefit from training on topics related to broadening participation in computing and CS career awareness (NCWIT, 2019); 5) educators who teach a new topic for the first time, such as CS, improve in confidence and content knowledge when they receive classroom coaching visits from content specialists (Joyce and Showers, 2002); 6) rural teachers who are separated geographically from a physical peer cohort of CS teachers gain confidence when participating in a CS professional learning community (Cooper et al., 2014); and 7) while most K-12 CS evaluations focus on single curricula and rarely demonstrate the highest level of evidence (WWC, 2012), this evaluation involves a multi-level, multi-outcome experimental design and a deep longitudinal study of thousands of students engaging in CS pathways offered at rural high schools.

A.2. Demonstration of Promising Strategies

This section documents some of the strategies that will be incorporated and evaluated by PACS in the form of strategic collaborations and engaging national curricula.

Engaging Curricula: Integrated and Stand-alone CS Content Courses:

This section introduces the core components of the PACS CS pathway.

CS-Infused Algebra with Bootstrap

Many students who enroll in college as STEM majors lack sufficient mathematics preparation to confidently progress through their major-focused courses. A UCLA survey found that 60% of all students who enter college as declared STEM majors drop out of *any* STEM major prior to graduation (Figueroa et al., 2013), often due to inadequate mathematics preparation. Students can memorize facts about mathematics, but they often fail to understand how to mathematically approach a new problem that does not fit their experience or the rules they memorized (NCTM, 2014). The last four testing cycles of the National Assessment of Education Progress (NAEP) shows only slight or flat progress in math that includes gender and racial differences (NAEP, 2011, 2013, 2015, 2017). Further, students nationwide display poorer mathematics proficiency in 8^{th} grade compared with 4^{th} grade. In Alabama, both racial and gender disparities were seen in mathematics NAEP scores (NAEP, 2011, 2013, 2015, 2017) and Alabama scored near the bottom of the national average. Even more alarming, those students who scored in the highest percentile within Alabama were still near the bottom nationally (Crain, 2016). Thus, as in most of the US, the proficiency of Alabama students decreased significantly between 4^{th} and 8^{th} grades (e.g., 31% in 4th, 21% in 8th), and racial and gender disparities became more pronounced during this period, especially in rural and high needs schools. This suggests that traditional methods of reaching lower performing students in mathematics requires a different approach, particularly in rural Alabama.

Secondary Mathematics classes are defined by the quality of lessons that are goal-oriented towards students' conceptual understanding of mathematics and engagement in mathematical practices tied to learning. High quality teaching in mathematics facilitates high-quality tasks, interactions, and student reasoning (Barker et al., 2004; NCTM, 2011; Stein et al., 2008; Stein et al., 2009). New curricula and pedagogical strategies are needed to help motivate students enrolled in Algebra to develop problem-solving skills contextualized in concepts and scenarios that they find compelling and of interest.

Bootstrap conveys mathematics concepts through projects based on customized video games and other content of interest to students. Each student designs his/her video game using mathematical concepts (e.g., order of operations, linear functions, function composition, inequalities in the plane, etc.). Thus, computational thinking skills (Wing 2006, 2008) are transferred form an algebra-rich programming context to an algebraic problem-solving context. Bootstrap Algebra maps to the current Alabama Math standards. The integration of Bootstrap into an Algebra course requires 25 hours of classroom instruction (Schanzer et al., 2018a, 2018b). A benefit of using Bootstrap as the first PACS pathway course is the higher enrollment potential. As a required course for graduation, a much larger group of students can gain first-exposure to CS within the situated context of mathematics.

Rigorous Evidence-Based High School CS Courses

Exploring Computer Science (ECS) is a year-long, evidence-based high school intro-level computer science curriculum focused on broadening participation in computing (Goode & Chapman, 2009; Goode & Margolis, 2011; Goode, Margolis, & Chapman, 2014). The core focus areas are problem-solving, computational practices, and modes of inquiry with a strong focus on equity in the context of a strong, ongoing teacher community of practice. Effective teaching with the ECS model includes engaging students in active learning, drawing connections to students' prior knowledge and experiences, scaffolding the learning process, continuously assessing students learning, providing clear standards and constant feedback, and encouraging strategic and metacognitive thinking. Initial success has already been realized with ECS in Alabama, with two cohorts of teachers trained over the past two years (Qazi et al., 2019). This initial success, with particular focus on the high representation of females and underrepresented students, will form a foundation of ECS expansion in PACS.

Several curricula satisfy the framework for AP CS Principles (CSP) and are endorsed by the College Board. The AP CSP course was developed with a clear and well-specified curriculum framework (College Board, 2017) that defines the conceptual Big Ideas and CT Practices that comprise the learning objectives and minimum standards for the course. **UTeach Computer Science Principles** is an AP CSP curriculum endorsed by the College Board. UTeach emphasizes teacher training and instructional support, a project-based approach to student learning, and a focus on engaging students from historically underrepresented groups (Beth & Moreland, 2017).

Equipping School Counselors with Strategies for Broadening Participation in Computing

The National Center for Women in IT (NCWIT) offers the **Counselors for Computing (C4C)** professional development, which provides professional school counselors with information and resources they can use to support ALL students as they explore computer science education and careers. The C4C training will be customized to address PACS needs (e.g., helping counselors understand all of the new curricula training available to their teacher colleagues and the possible pathways, as well as the Alabama state context for CS/IT opportunities in our state). The focus on combining efforts among counselors and teachers in this large-scale study allows us to look at the whole student by evaluating the effects of interest, awareness and self-efficacy among students.

A State-wide Week of CS Professional Development: During the summers of 2016 and 2017, project collaborator Dr. Jeff Gray was a co-organizer of a national effort called CSPdWeek (http://www.cspdweek.org/), which was hosted both years in Golden, CO, at the Colorado School of Mines. CSPdWeek brought over 300 teachers from all over the nation to train on four different curricula (Bootstrap, ECS, and an AP CSP special workshop supported by the NSF), and other training (e.g., C4C and a host of evening receptions with prominent speakers). CSPdWeek endeavored to provide a rich social and collegial experience among many teachers who were learning CS for the first time. PACS will follow the CSPdWeek model to build culture and a sense of community and camaraderie among multiple cohorts of teachers who will be sharing new experiences. The CSPdWeek event will occur on the campus of the University of Alabama during one full week in the summer, with some teachers returning over the Fall and Spring for additional training (e.g., ECS, which also brings each cohort back for a second summer of training after a first year of classroom experience). In addition to the professional development sessions offered during the day, PACS seeks to inspire participations through engaging nationally known equity-focused CS educators to speak at dinners. As a very special evening reception, Mercedes-Benz (whose North American headquarters are 20 minutes from the campus) will host a special evening at their manufacturing plant, including a meal, tours, and a chance to interact with Mercedes engineers to understand the global impact of computing in industry, as a context to share back to their students in the Fall (please see MBUSI letter).

Across the duration of the project and the four supported cohorts of teachers/counselors, PACS has the potential to provide over 440 teacher training experiences (some teachers may train on more than one curricula), up to 240 high school counselors, and engage over 60,000 student course experiences during the five-year project period (Table 1).

Table 1: Number of teacher/counselor training experiences and student course experiences (T - Teachers; S - Students; C - Counselors trained per year/curricula)

	Bootstrap Algebra	*ECS*	*CSP*	*C4C*
2020-2021	60T (4,500S)	30T (600S)	20T (400S)	60C
2021-2022	60T (9,000S)	30T (1,200S)	20T (800S)	60C
2022-2023	60T (13,500S)	30T (2,400S)	20T (1,600S)	60C
2023-2024	60T (18,000S)	30T (4,800S)	20T (3,200S)	60C
TOTAL	240T (45,000)	120T (9,000S)	80T (6,000S)	240C

The Alabama Math, Science, and Technology Initiative (AMSTI): The Alabama Math, Science, and Technology Initiative (AMSTI) has an existing structure of support with STEM specialists in each of the 11 educational in-service regions across Alabama (please see http://www.amsti.org). AMSTI math specialists will be trained in Bootstrap to assist teachers with integrating CS into their Algebra courses during the school year. Leveraging AMSTI specialist support will build capacity and benefit PACS efforts in recruiting and sustaining teachers by being a regional advocate, supporting informal classroom observation, and a conduit for feedback/data on the project. Most importantly, they will be the regional coaches for Bootstrap for supporting local teachers and also coordinate the hosting of student Summer Institutes and weekend study sessions. These specialists are in strategic geographic positions (please see Appendix I for a map of the six selected AMSTI sites) to assist teachers in connecting their Algebra courses to the new Bootstrap content, as well as the new Alabama Computer Science standards.

A+ College Ready: A+ College Ready (see https://aplusala.org) is a non-profit organization that leads Alabama's statewide effort to offer teacher professional development and student experiences that increase the number of students in Alabama enrolled in math, science, English, and social studies Advanced Placement (AP) courses, earn qualifying scores on AP exams, and attend and succeed in college. Through A+ College Ready's efforts across 67 districts, Alabama has led the nation in percentage growth of qualifying AP scores in math, science and English for students overall, and is third in the nation for minority student success. They have recently added support for AP CS Computer Science. Carol Yarbrough, CS Director at A+ College Ready, will assist in identifying and preparing the Teacher Leaders who will offer the student Summer Institutes and weekend study sessions that are hosted at the regional AMSTI in-service sites.

Exit Pathway to Alabama Workforce Development Opportunities: The PACS pathway will prepare an exit point for further credentialing as part of Alabama's implementation of the Workforce Innovation Opportunity Act (WIOA). Stackable, trackable, portable, and transferable industry-recognized credentials that are linked to fast-growing, high-wage, and high-demand career pathways in CS will create opportunities for in-school youth on work-based learning and credential attainment. A credential currency will also signal to young people, who are economically disadvantaged and socially at-risk, that entry into a skill- and competency-based career pathway in CS is also a path into economic security.

A.3. Project Approaches to Early Phase Established Priorities

PACS will identify two Absolute Priorities and the Competitive Preference Priority.

Absolute Priority 1 – Demonstrates a Rationale: Our hypothesis for the Randomized Control Trial (RCT) study is that the integration of CS through Bootstrap into high school Algebra classes by effectively prepared teachers will improve students' algebraic and computational thinking skills.

There is a new and emerging body of research to support the relationship between computing activities and students' mathematical achievement. The National Council of Teachers of Mathematics stated in 2008 that programming instruction has the potential to positively impact students' mathematical understanding and ability. Schenke, Rutherford, and Farkas (2014, WWC) showed **experimentally** that use of Spatial Temporal Mathematics (ST Math) to engage 3rd-5th grade students through game-like activities (aligned to California State Standards) significantly improved students' basic number sense skills (N=10,860, effect size=0.14) through software embedded design elements related to number sense. Grover, Pea, and Cooper (2015) found that a blended CS and mathematics course resulted in significant student growth in students' computational learning and transfer compared with a control condition. Kebritchi, Hirumi, & Bai (2010) found students' use of computer games had a positive effect on students' mathematical achievement (N=193, effect size=.095).

The Bootstrap approach to teaching algebraic concepts is particularly promising. A technology-based approach to algebraic tasks can improve students' mathematical learning through reducing the cognitive load of traditional algebraic work through rapid computation, rich visualization, concrete examples, and conceptual similarities. Lee (2013) conducted a feasibility study and found that middle school students who completed the Bootstrap course gained a significantly better understanding of variables and a suggestive improvement in understanding functions (N=45, effect size=.01). Schanzer (2015) conducted a feasibility study (N=106, effect size not provided) that demonstrated how a Bootstrap approach to algebra improved students' use of functions, problem-solving transfer, and modeling, relative to students in a matched comparison group; teacher technological pedagogical content knowledge (T-PCK) and mathematical knowledge for teaching (MKT) were shown to be mediating factors.

Absolute Priority 3 – Field-Initiated Innovations-STEM: In Alabama, 53% of students are in poverty and high-need, much higher than the national average; in fact, two counties in Alabama are among the most impoverished in the nation. The PACS project aims to improve student achievement and attainment for high-needs students by supporting new opportunities to explore emerging computer science pathways in their school district. Teachers trained as a cohort within the PACS project bring these opportunities to their school. The field-initiated results of PACS will be nationally significant due to the new and relatively untested educational practices of: 1) an experimental context to conduct one of the largest longitudinal studies of CS competency and interest across high school; 2) large-scale collaboration of counselors and teachers to address concerns of equity, while raising awareness of opportunities in computing among high-needs students; 3) the number of teachers trained and students impacted, using a pathway that combines integrated CS in Algebra with stand-alone authentic CS courses later in the pathway.

PACS Teacher Recruitment Plan and Stipends

Teachers will be recruited into PACS from all across Alabama (primarily math teachers for Bootstrap; math, science and career tech teachers in ECS and AP CSP). A call for participation will be sent from the ALSDE to all Superintendents. Compensation for participating teachers includes the following: 1) A stipend of $125 per day of PD that will be paid incrementally upon satisfactory completion of scheduled PD milestones; 2) Full coverage of the cost of PD, including all travel, lodging, and meal expenses associated with each PD event; and 3) access to all curricula resources and learning communities over the school year. Each teacher supported by PACS must have a contract signed that has explicit statements of commitment from the teacher, their Principal, and the Superintendent of the school district.

There is an additional incentive for PACS-sponsored teachers. On April 19, 2018, Alabama Governor Kay Ivey signed HB 261, which created the Alabama Math and Science Teacher Education Program (AMSTEP) as a loan repayment program for eligible math and science teachers. Once a secondary certification pathway is approved for CS, future CS teachers will be eligible to participate in AMSTEP. A certification bill is proposed for the 2019 legislative session (2019 HB 216).

Competitive Preference Priority: The main PACS goal, as described throughout this proposal, is focused on improving student achievement in computer science, primarily for high school students in high-need rural schools. According to the University of Alabama Center for Business and Economic Research (CBER, 2019), all of Alabama's 10 most rural counties are majority African American, ranging from 58% (Dallas County) to 86% (Macon County) of the population identifying as African American. These counties represent the core of the PACS recruitment regions for the introduction of high school CS pathways.

B. Project Design & Management Plan

B.1. Project Goals, Objectives, Outcomes, and Activities

The PACS goals, objectives, activities and outcomes are outlined in Table 2.

Table 2: Project Goals, Objectives, Outcomes, Measures, and Milestones
Goal A: Establish and expand computer science pathways for rural/town high schools
Objectives: 1. Expand local partnerships to develop CS pathways

Outcomes, **Measures,** and **Milestones**
1a. Leverage existing relationships among rural/town schools and LEAs/AMSTI Centers to develop CS Pathway. **Measure:** 90% of schools are <30 miles of a regional AMSTI center
1b. Increase number of schools in Alabama rural/town districts that offer full CS Pathway with trained counselors. **Milestone:** Add 10 schools per year with full CS Pathway (Bootstrap Algebra, ECS, AP CSP, C4)
1c. 6 AMSTI Centers make school-based Bootstrap coaching available to cohort 1-4 teachers
1d. UA and TU provide infrastructure support for ECS. **Milestone:** 6 teacher-leaders across AMSTI regions by year 5
1e. A+ College Ready cultivates teacher-leaders for AP CSP. **Milestone:** 12 teacher-leaders across AMSTI regions by year 5

Goal B: Prepare teachers and counselors to implement CS pathways within school districts to achieve CS success for all

Objectives:
2. Implement PD program to improve instructor competencies to deliver innovative CS Pathway courses in rural/town school settings: PCK, curriculum implementation, technical expertise, work-based readiness
3. Provide ongoing and effective coaching support for classroom implementations
4. Increase teacher effectiveness in CS
5. Foster professional learning community
6. Retain trained, certified CS teachers in rural/town Alabama
7. Prepare and support counselors in providing Career and Workforce Readiness awareness to students, foster teacher learning community

Outcomes, **Measures,** and **Milestones**
2. Teachers attend CSPD week each summer that includes 40 hours of face-to-face training for Bootstrap, ECS, or AP CSP; ECS teachers subsequently attend 2-day fall, 2-day spring, and 5-day second summer additional trainings; AP CSP teachers attend 2-day teacher summit in the fall. **Milestone:** Hours of PD provided for cohorts 1-4: 45 for Bootstrap, 72 for ECS, 56 for AP CSP
3. AMSTI classroom mentoring provided annually for Bootstrap teacher. **Measure:** Annual teacher survey; **Milestone:** 90% of Bootstrap teachers utilize coaching which they rate as "effective" in cohorts 1- 4
4. Increase teachers' CS efficacy beliefs, pedagogical confidence, preparedness, outcome expectancies, attitudes toward 21st century learning and teaching **Measure:** 6 T-STEM scales and 3 teacher preparedness scales; **Milestone:** 75% of teachers make gain, cohorts 1-4
5. Teachers participate in virtual learning communities led by AMSTI specialists (Bootstrap) and teacher-leaders (ECS, AP CSP). **Measure:** Number of measured interactions within community (e.g., to online forums); **Milestone:** 90% of teachers with 20+ annual community interactions in cohorts 1-4
6. Sustain trained CS teacher pool. **Milestone:** 90% of teachers are retained in courses for which provided PD by project's end
7a. Increase counselors' understanding of computing and confidence in guiding students towards computing education and careers. **Measure:** Counselor survey; **Milestone:** 95% of counselors report having better understanding of computing and greater confidence in guiding students in cohorts 1-4
7b. Counselors provide information to all students: (1) available CS courses, (2) internships and co-op opportunities, (3) credentials for in-demand career pathways. **Measure:** Workforce readiness implementation survey; **Milestones:** 90% provide info to all students (cohorts 1, 2), 100% provide info (cohorts 3, 4)

Goal C: Increase the number of students taking CS Pathway courses and increase students' computational thinking, CS learning, and CS interest and preparation for Career and Workforce Readiness experiences
Objectives: 8. Develop and deliver AP CSP Summer Institute and academic year Saturday sessions for rural/town students 9. Deliver evidence-based CS: Bootstrap, ECS, and AP CSP in rural/town high schools 10. Conceptually challenging and engaging Bootstrap instruction 11. Increase students' skills in Bootstrap: Algebra and computational thinking practices 12. Rigorous, relevant, and engaging ECS instruction 13. Increase students' computational thinking in ECS 14. Rigorous, relevant, and engaging AP CSP instruction 15. Increase student content knowledge and computational thinking practices in AP CS Principles 16. Increase students' CS attitudes: confidence, interest, belonging, perceptions of CS usefulness and encouragement 17. Increase career and workforce readiness of students, with particular focus on rural, underrepresented, and low income students *Outcomes,* **Measures,** and **Milestones** *8. Students enroll and attend AP CSP Summer Institute and AY sessions.* **Milestones:** 80% of AP CSP students who attended Summer Institute attend both fall and spring regional sessions (Saturday sessions) in cohorts 1-4 *9. Implement evidence-based CS that covers Alabama CS Standards.* **Measure:** Basics Study Teacher Questionnaire; **Milestones:** Bootstrap covers 25% of CS standards, ECS, AP CSP cover 100%, cohorts 1-4 *10. Deliver conceptually challenging instruction that engages students in algebraic problem-solving and involves aspects of computational thinking* **Measure:** MCOP^2; **Milestones:** 80% of observed courses reached quality level 3 of 4, cohorts 2-4 *11. Increase students' algebraic skills and computational thinking for selected rural/town student sample.* **Measures:** Algebra word problems, computational thinking practices assessment; ***M*ilestones:** 60% of cohorts 2-4 students exceed the previous cohorts' mean scores *12. Deliver rigorous, relevant instruction that effectively engages student in learning experiences.* **Measures:** Rigor, Relevance, and Engagement rubrics (ICLE 2015); **Milestones:** 80% of observed ECS courses reach "Developed" levels in cohorts 2-4 *13. Increase students' computational thinking for rural/town students in ECS courses.* **Measure:** Computational thinking practices assessment; **Milestones:** 60% of cohorts 2-4 students exceed the previous cohorts' mean scores *14. Deliver rigorous, relevant instruction that effectively engages students in learning experiences.* **Measure:** Rigor, Relevance, and Engagement rubrics; **Milestones:** 80% of observed AP CSP courses reach "Developed" levels in cohorts 2-4 *15a. Increase exam-taking of rural/town students in AP CSP courses.* **Measure:** AP CSP exam results for participating schools; **Milestones:** 80% of students. *15b. Increase qualifying scores for rural/town districts for AP CSP exam.* **Measure:** Alabama statewide May 2018 results (57% qualifying, n=1511); **Milestones:** cohort 1 rate= baseline, cohort 2=baseline+2%, cohort 3=baseline+4%, cohort 4=baseline+6% *15c. Increase qualifying scores for students with supplemental experiences (Summer Institute, AY work) on AP CSP exam.* **Milestones:** 60% of students with supplemental AP CSP exceed study sample, cohorts 1-4 *16a. Increase Pathways course enrollment of students to match rural/town school demographics.* **Measure:** % female, %underrepresented, %low income students; **Milestones:** within <15% (cohort 1), <10% (cohort 2), <5% (cohort 3), equal (cohort 4) *16b. Increase students' CS attitudes: confidence, interest, belonging, usefulness of CS, perceptions of*

encouragement. **Measure:** Student Computer Science Attitude Survey (Haynie 2017); **Milestones:** 75% of student sample gain on all scales, cohorts 1-4
17a. Increase students' participation in career and workforce readiness activities. **Measures:** Student attendance logs; **Milestones:** 80% of cohort 1- 4 students participate in at least one CS-related career and workforce readiness activity/workshop
17b. Increase students' confidence and efficacy in CS, 21st century learning skills, interest in CS/STEM careers. **Measures:** S-STEM Middle/High School Measures (FIEI, 2012), Computer Science Interest Survey; **Milestones:** 75% of student sample gain on all scales, cohorts

B.2. Management Plan, Responsibilities, Timelines, Milestones

Timelines and Milestones: The "Activities by Project Year" specified in Table 2 define the specific years in which activities will be explored to address the PACS objectives. Each year, there are frequent activities at an implementation level that are not defined in Table 2, such as: 1) Recruitment of new teacher cohorts each Spring; 2) summer PD during a common week each June or July, with associated evaluation instruments (pre/post-surveys); 3) each Fall, a random sample of students will be selected and asked to respond to project evaluation instruments, while some curricula (e.g., ECS) have additional training sessions for all new cohorts trained in the previous summer; 4) similar to the Fall, each Spring will have an application of evaluation instruments to the randomly sampled students from the Fall, and an additional cohort training, with the whole process repeating again for the next cohort (e.g., a new wave of recruiting).

PACS Leadership Team: In addition to the ALSDE, other partners on PACS include: A+ College Ready (non-profit), University of Alabama (CS/Math Education), Tuskegee University (STEM equity), Haynie Research and Evaluation (evaluation), and Mercedes-Benz (industry).

The PACS Leadership team is comprised of the following who have specific project responsibilities (detailed resumes can be found in Appendix B): **1) Dawn Morrison** is an Education Administrator with the ALSDE and has been a key collaborator on CS expansion across the ALSDE for over a decade. Dawn serves as a member of the Governor's CS Advisory Council and was a member of the K-12 CS Standards writing committee. She will support the PACS research study at various levels of implementation, including the main project management of PACS within the ALSDE. She will also compile baseline data for evaluation. **2) Dr. Sandy Ledwell** is the Alabama State STEM Director who leads AMSTI. She will lead the coordination of all AMSTI specialists who provided classroom support for Bootstrap teachers, as well as manage the logistics of the student Summer Institutes and weekend study sessions. **3) Dr. Jeff Gray** is a Professor of Computer Science at UA. He is a certified College Board instructor for AP CSP and has been piloting the AP CSP course for the College Board since 2011. He has extensively trained Alabama in-service teachers on CSP (49 teachers), Code.org K5 (over 1,400 teachers), and has offered a MOOC through Google CS4HS to train over 2,000 teachers nationally (summer 2015 and 2016) (Gray et al., 2016). Jeff co-Chairs the Governor's CS Advisory Council and assisted in writing the new Alabama CS Standards. He will be responsible for organizing the summer and academic year PD training sessions, helping with the online community of practice, and assisting in recruiting teachers. **4) Dr. Jeremy Zelkowski** is the Director of the Secondary Education Mathematics (SEMA) Pre-Service Teacher (PST) program in the Department of Education at UA. He teaches and observes SEMA PSTs, chairs the national NCTM Affiliates Relations Committee, and is the past-President of the Alabama Council of Teachers of Mathematics (ACTM). He will assist in coordinating formal observations of teaching and guide the project on matters of mathematics education related to Bootstrap Algebra. **5) Dr. Rebecca Bartel** is a faculty member at UA who coordinates the CSP course at UA. She is also a project-lead on an NSF project that is preparing pre-service Education majors to become future AP CSP educators. She will assist with the summer PD training and the teacher online communities of practice. **6) Dr. Mohammed Qazi** is a Professor of Mathematics at Tuskegee University (TU). He is the leader of several NSF-funded projects to establish computer science in Alabama's Black Belt Region. He also served on the

Alabama CS Standards writing team and is a member of the Governor's CS Task Force. On the PACS project, he will be responsible for co-organizing and implementing the summer and academic year training sessions, assist with student recruitment and providing mentorship to Bootstrap Algebra teachers through the online community of learners. **7) Carol Yarbrough** is a former high school CS teacher who is content director for A+ College Ready, a non-profit that offers training, mentoring and support for AP training across Alabama. Carol was a member of the College Board AP CSP Development Committee, a College Board Consultant delivering APSIs for AP CSP, and a Code.org facilitator for AP CSP. Carol will help to identify and prepare teacher leaders who will offer the student Summer Institutes and weekend study sessions. **8) Dr. Kathleen C. Haynie** is the Director of Haynie Research and Evaluation (HRE) and has served as the external evaluator for 9 NSF and Google-funded initiatives designed to broaden student participation in CS and bring CS Principles to national scale. As Co-PI of the CSONIC project (NSF #1649671) and Director of the CS Impact Network, she drives professional networking and resource sharing among CS evaluators. She will conduct the project's external evaluation according to the description in Section C and Appendix G.

B.3. Feedback and Continuous Improvement

PACS's success relies heavily on continuous high-quality performance feedback for program refinement and improvement **(see Appendix G)**. The evaluation team will participate in quarterly Project Leadership Team meetings to build consensus on critical evaluation questions, methods, instruments, data collection protocols, and reporting formats. This participatory approach to utilization-based evaluation (Guijt, 2014; Zukoski & Luluquisen, 2002; Patton, 2008) will ensure data is used strategically on a regular basis to provide feedback to refine implementation and make programmatic changes. Through continuous monitoring, the evaluation team will provide periodic feedback to each AMSTI site and teacher learning community, and will triangulate the data to provide a synthesis of program-wide, evidence-based data. Evaluation results will be shared through interim and annual reports, survey and focus-group snapshots, and in-person briefings by the evaluation team to the Advisory Board, PACS Leadership Team, A+ College Ready, and the ALSDE. This approach builds stakeholder ownership, increasing the likelihood that results will be used to improve the program and achieve positive outcomes. The evaluation team will chart actual progress against quarterly targets to support continuous improvements and iterative development.

*Advisory Committee***:** To assist with the formative assessment, advise on gathering intervention efficacy, and offer adaptations that may be needed to the project focus each year, the project will be informed by the input of an external advisory board. A diverse group of national leaders with expertise in CS, computational thinking, cognitive psychology, and educational assessment will be provided with a summary of annual evaluation results. They will be asked to visit Alabama each year for one day to provide advice and direction on the focus of the project. The PACS advisory panelists that have accepted our invitation include: **Assessment Expert and Certified WWC Reviewer:** [redacted] [redacted] [redacted]; **K-12 Education Policy Expert**: [redacted]; **K-12 Computer Science Education Expert**: [redacted] **K-12 STEM Diversity Specialist and Cognitive Psychologist**: [redacted] **Computer Science Educator and AP CSP Curriculum Framework Developer:** [redacted]

B.4. Project Dissemination Plan

We will provide access to all intervention effectiveness results and evaluation data on our website and by request. Our evaluator will also share evaluation findings with the US Department of Education and the What Works Clearinghouse. The PACS website will contain developed teaching resources, videos and photos of the various project activities, and evaluation/assessment results. We will present a description of the results on the project website and report these in presentations at professional conferences and publications in professional journals. The ACM SIGCSE conference will be the preferred venue for project submissions that focus on the CS topics of the project. We will also plan to submit the final results of PACS to ACM Transactions on Computing Education. Presentations will be given at our state meetings on mathematics education, as well as the Governor's Annual CS Summit.

C. Project Research and Evaluation

C.1 Evaluation Methods: Project Effectiveness Meeting WWC Standards without Reservations

The evaluation questions, data sources, and analysis methods for the Randomized Control Trial (RCT) efficacy study is summarized in Table 3.

Table 3: Efficacy Study Summary

Questions	Data sources	Analysis
Efficacy Study (Cohort 1, 2020-2022)		
RQ1.1 What effect does participation in a CS-infused algebra course have on rural students' **algebraic problem-solving and computational thinking**? RQ1.2 What effect does participation in a CS Pathways course have on rural students' **computational thinking?** RQ1.3 What effect does participation in two CS Pathways courses have on rural students' **computational thinking?**	**Algebraic word-problem assessment** **Computational thinking assessment**	**Experimental:** Randomized Control Trial (RCT) with hierarchical linear modeling (HLM)
RQ2.1 What effect does participation in a CS-infused algebra course have on rural students' **interest in CS/STEM learning and careers?** RQ2.2 What effect does participation in a Pathways CS course have on rural students' **interest in CS/STEM learning and careers?** RQ2.3 What effect does participation in two CS Pathways courses have on rural students' **interest in CS/STEM learning and careers?**	**S-STEM survey** **Administrative Data** (transcripts, enrollment records)	

Effective Strategies Suitable for Replication: The efficacy study will use stratified assignment at the school level to meet the **What Works Clearinghouse (WWC) Evidence Standards without reservations** (WWC, 2018). School assignment to treatment or control groups will be done using clustered random assignment of rural and town schools within AMSTI district. To assure comparability given many selection constraints, baseline equivalence across conditions will also be analyzed (WWC, 2012; WWC, 2018). Baseline and analytic characteristics for the 9^{th} grade (treatment and control) sample and the $10\text{-}11^{th}$ grade (treatment and control) sample will include student sample sizes, baseline mathematics achievement (e.g., 8^{th} grade state-level math test for the 9^{th} grade sample), locale codes (rural, town, suburb or urban), AMSTI region, and baseline CS interest and CS/STEM career interest. Students in the treatment group will participate in CS-infused algebra courses (9^{th} grade) or CS Pathways courses (10^{th} and 11^{th} grades: ECS, AP CSP) during the 2020-2021 year in which teachers receive summer PD and ongoing support in the form of a professional learning community and coaching; students in the control group will participate in regular algebra courses (9th grade) or no CS course (10th and 11th grades) during the 2020-2021 year by teachers who do not yet have access to the PD resources of the PACS project. Enhanced algebra courses will include 25-30 hours of CS (Bootstrap) integrated into the regular algebra courses. In the second year of the study, 2021-2022, 10th grade students in the treatment group may elect to participate in an ECS course if available; 11th grade students in the treatment group may elect to participate in an AP CSP course if available. Therefore, a subset of the treatment group students will participate in two CS Pathways courses in 2020-2022 (either Bootstrap followed by ECS, or ECS followed by AP CSP). Students in the control group will not participate in a CS course in 2021-2022.

The first cohort of schools, teachers, and students[1] will enter the study for PD in summer 2020 and will include 60 9th grade algebra teachers, 30 ECS teachers, and 20 AP CSP teachers from a total of 60 schools. Teachers from rural and town schools will be targeted for recruitment into PD; recruiting will continue until the pool of potential participants is comprised of at least 75% of schools with rural codes (NCES codes of 31-33) or town codes (NCES codes of 41-43; Geverdt, 2015). Prior to summer 2020, 240 schools and about 340 teachers will be recruited for cohorts 1, 2, 3, and 4. Rural and town schools (about 180 schools of 240) will be assigned to one of the four cohorts using a cluster randomized assignment design (i.e., equal numbers of rural/town schools within each of six AMSTI regions) the treatment and control groups are expected to be equivalent in both observed and unobserved characteristics, and to differ only in terms of the

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[1] Cohort is defined by the time period of teacher PD. Cohort 1 teachers will begin PD in summer 2020 PD and students will take CS-infused or CS courses in 2020-2021. Cohort 2 teachers will begin PD in summer 2021 PD, Cohort 3 teachers will begin PD in summer 2022, and Cohort 4 teachers will begin PD in summer 2023.

approach to 9th grade Algebra and the addition of CS Pathway courses. Any suburban or urban schools will be assigned to cohorts 2 or 4. Cohort 1 (60 rural and town schools) will serve as the efficacy study treatment condition; teachers will begin PD in summer 2020. Cohort 3 (60 rural and town schools) will serve as the control condition for the efficacy study (2020-2022) and will begin PD in summer 2022. Cohorts 2 and 4 (120 schools from various locales) will not participate in the efficacy study; teachers will begin PD in summers 2021 and 2023, respectively.

Parental assent and student consent to participate in the research portion of the program will be requested from students in the **earliest** grade-appropriate algebra that a participant teacher offers in a day (probably first or second period). Approximately 270 students (27 students for each of 10 teachers) will comprise each of the following groups in 2020-2021: 9th grade treatment, 9th grade control, 10th grade treatment, 10th grade control, 11th grade treatment, and 11th grade control for a total of 1620 students. Student and classroom-level attrition will be minimized through use of several strategies that include: (1) working closely with participating schools through professional learning communities, (2) monitoring teacher activities, particularly through AMSTI coaching, (3) providing virtual conferencing tools or phone numbers to allow teacher participants to communicate with curricula providers and project staff, and (4) providing alternative testing and survey dates for absent students.

*Performance Data on Relevant Outcomes***:** Program effects will be evaluated for three main outcomes: algebraic problem-solving, computational thinking, and CS interest and CS/STEM career interest. To ensure validity and reliability, algebra skill attainment will be measured for 9th grade students using an algebraic problem-solving assessment (e.g., Schanzer, Fisler, Krishnamurthi, 2018a); computational thinking will be measured for all 9th, 10th, and 11th grade students using a summative CT Practices assessment (Snow, Tate, Rutstein, & Bienkowski, 2017).

The S-STEM, a validated measure of student attitudes toward CS and interest in CS/STEM careers (Unfried, Faber, Stanhope, & Wiebe, 2015) will be given to all students in the efficacy study. The evaluation team will establish data sharing agreements with the ALSDE for covariates (demographic variables, student transcripts, course-taking).

Reported results will include the number of schools assigned, the number of schools in the analytic sample, school-level attrition rate, the number of students at baseline in schools that did not drop out, and the number of students in the analytic sample. Internal consistency reliabilities for all measures will be reported and evaluated for adequacy. Only complete cases will be included in the analysis, and pre-intervention characteristics will be included as covariates. Assuming 540 students will be matched per grade (N=270 treatment and 270 control students) across 20 schools (81 students per school) yields a Minimum Detectable Effect Size (MDES) of 0.197 (alpha = 0.05; power=.80, ICC = 0.05). This MDES is sufficient to detect both learning and attitudinal impacts (with the accepted limits of a small effect size). If statistical assumptions are met, analyses within a hierarchical linear modeling (HLM, Raudenbush & Bryk, 2002) approach will be conducted to accommodate the nested nature of the design. The impact of the intervention on student outcomes will be estimated using a series of three-level hierarchical linear models, with students nested within schools nested within AMSTI regions, and treatment at the school level. Group assignment (treatment or control) is the independent variable, student outcomes (student algebraic problem-solving, computational thinking, CS interest, CS/STEM) the dependent variables, and school is a moderator variable. If statistical assumptions are not met, nonparametric (e.g., goodness-of-fit) tests will be used. Internal consistency reliabilities (Cronbach's alpha: Cronbach, 1951) will be reported and evaluated for adequacy. Effect sizes will be determined and evaluated using MDES for all significant findings.

<u>Key Project Components, Mediators, Outcomes, Measurable Thresholds:</u> It is possible that particular subgroups of students may benefit more from the intervention than other subgroups. An interaction term between the treatment and student subgroup characteristic will be added to the HLM model for the overall impacts to determine how student characteristics may interact with the program to determine student outcomes. The interaction effects between the treatment condition variables and particular baseline characteristics of students (e.g., grade level, gender, racial/ethnic group, prior math achievement), teachers/classrooms (years of teaching, certifications) and schools (rural or town locale, % free and reduced price lunch, districts' elementary school participation in prior Code.org training) will enable us to assess whether the impacts were greater or smaller under particular circumstances.

C.2 Evaluation Methods: Implementation Fidelity

Using observational and teacher survey methods, implementation fidelity of PACS courses will be evaluated for quality across teacher, school districts, and cohorts (Table 4).

<u>Sampling plans</u>: Course implementations of 10 teachers per course, 2 observations per teacher per course will be carried out by AMSTI specialists (for Bootstrap) and by HRE evaluators (for ECS and CSP) in all four years of classroom implementation.

Table 4: Fidelity of Implementation

Questions	***Data sources***	***Analysis methods***
Fidelity of Implementation (Cohorts 1-4)		
FIQ1. To what extent are 9th grade students' engaged in Algebra experiences that can improve algebraic and computational thinking and CS attitudes? FIQ2. To what extent are students engaged in CS courses that can improve CS learning and attitudes? FIQ3. To what extent are standards-based PACS courses implemented with fidelity? FIQ4. To what extent are the full CS pathways established and what is the student impact?	Bootstrap Classroom Observations (MCOP^2) ECS and CSP Classroom Observations (ICLE RRE Rubric) Basics Teacher Questionnaire	Descriptive statistics and qualitative results by and across cohorts, conditions (e.g., AMSTI region) and courses

<u>Effective Strategies Suitable for Replication</u>: Implementation fidelity will be evaluated with observational measures and teacher implementation questionnaire for each course by AMSTI specialists in each local region. For Bootstrap, the Mathematics Classroom Observation Protocol for Practices (MCOP^2, Gleason, Livers, & Zelkowski, 2017, 2018) will be used to measure the degree to which actions of teachers and students in mathematics classrooms align with practices recommended by national organizations and standards using a two-factor structure of Teacher Facilitation and Student Engagement. Teachers will complete the BASICS study teacher questionnaire measure (Outlier Research and Evaluation 2017), adapted for Bootstrap, to determine: (1) how Bootstrap materials are used in practice; and (2) contextual factors that influence teacher use of the Bootstrap materials. For Exploring Computer Science and AP CS Principles courses, the ICLE Rigor, Relevance, and Engagement Rubrics (International Center for Leadership in Education 2015) will be used as classroom observation measure of quality levels (beginning, emerging, developed, or well-developed) for conceptual rigor (i.e., thoughtful work, high-level questioning, academic discussion), relevance (i.e., meaningful work, authentic resources, learning connection), and learner engagement (active participation, learning environment, formative process and tools). These rubrics will be used to measure the degree to which ECS ad AP CSP classroom implementations use active, engaging practices emphasizing problem-solving and conceptual approaches, connecting learning to meaningful work. Teachers will complete the original BASICS teacher questionnaire for ECS and an adapted version for AP CSP to determine: (1) how course curricular materials are implemented; and (2) contextual factors that influence course implementations.

Performance Data on Relevant Outcomes: For Bootstrap classes, MCOP^2 results will be calculated for two outcome scores: (1) student engagement in math practices [FIQ1 in Table 4], and (2) teachers facilitation of math practices [FIQ3]. Descriptive statistics will be calculated comparing observations across AMSTI regions and cohorts [FIQ1]. For ECS and CSP, ICLE results will be calculated for three outcome scores: (1) rigor, (2) relevance, and (3) learner engagement [FIQ2]. For both measures, observational scores will be summed to an overall quality index, and average per classroom quality will be calculated across observations. The Basics Teacher Questionnaire results will be calculated for are fidelity of implementation (e.g., completion of course units and lessons). Descriptive statistics based will be used to determine the fidelity of implementations by course and year; differences by AMSTI region and course type will be synthesized in terms of implementation successes and challenges and used to inform subsequent teacher PD cycles [FIQ3]. The implementation of course pathways by school (establishment of pathways, quality of implementations) will be determined [FIQ4] and student outcomes (e.g., computational thinking, CSP content knowledge, interest in CS/STEM careers) will be conditioned on students' participation in course pathways to provide evidence for the cumulative effect of different pathways on student success [FIQ4].

Evaluation Methods: Continuous Project Improvement: The project logic model and descriptions of measures and other continuous project improvement evaluation approach are provided in Appendix G.

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