SEED Grant 2020 Narrative: Clemson University's STEM Teacher Learning Progression (CU-TLP)

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Clemson University's STEM Teacher Learning Progression (CU-TLP)

INTRODUCTION

In response to *Absolute Priority 1* ***(AP1)*** and *Competitive Preference Priorities 1-3* ***(CPP1-3)***, **the goal of Clemson University's STEM Teacher Learning Progression (CU-TLP) is to create a replicable model that identifies and supports personalized professional development pathways designed to improve: (1) STEM teacher effectiveness, (2) STEM teacher retention, and (3) student achievement in South Carolina's high-needs, high-poverty middle schools** (grades 6-8). CU-TLP will use a collaborative filtering algorithmic **recommender system,** a set of data science analytics and machine logic, to guide the collection of teacher and school needs assessment data and to model the personalized professional development pathway (PPDP) output for each STEM teacher. The PPDP recommends evidence-based, personalized professional development (PD) experiences ***(AP1.2)*** in STEM, including computer science, and socio-emotional skill development in the form of stackable, advanced credential options (micro-credentials, courses, endorsements, and programs) to advance teacher competencies ***(AP1.3, CPP1, CPP2)***.

The results of these efforts will help retain STEM educators in South Carolina (SC), particularly within Qualified Opportunity Zones (QOZ) ***(CPP3)***, who are adequately prepared to deliver rigorous instruction in STEM fields thus resulting in access to high quality STEM learning for all and increased student achievement (Darling-Hammond, Hyler, & Gardner, 2017; National Science & Technology Council, 2018). CU-TLP will investigate the impact of personalized PD on teacher effectiveness, teacher retention, and student achievement, while basing the intervention on the best available evidence, research practices, and prior experience.

A. QUALITY OF PROJECT DESIGN

A1. Project Represents an Exceptional Approach

For more than a decade, researchers have increasingly recognized that conventional, one-size-fits-all approaches to PD accomplish little to improve teachers' professional learning (Caddle, Bautista, Brizuela, & Sharpe, 2016; Darling-Hammond et al., 2017). Teacher PD is most effective in improving instructional practices and increasing student achievement when it is aligned to both teacher and school needs and when it is collaboratively grounded in inquiry, reflection, and experimentation (Borko & Livingston, 1989).

Teachers and school leaders have been requesting more personalized PD that is responsive to individual interests, skills, career stage, school needs, and context (Martinez, 2019) that is also consistent with adult learning theory (Trotter, 2006); but until recently, the technological capacity to both design and deliver meaningful, truly personalized PD has been lacking. Ongoing advances in computational techniques associated with recommender systems, together with expanded, focused learning opportunities, have put personalized PD within reach. CU-TLP focuses on **supporting effective teachers** in SC by collaboratively uniting STEM teachers, school leaders, computer scientists, and PD facilitators through a supportive, technology-enabled system of personalized professional learning and growth for teachers in high-needs, high-poverty schools ***(AP1)***. CU-TLP represents an **exceptional approach** to this priority by pairing human expertise with a recommender system to enhance the traditional process by which we assess, recommend, and implement STEM teacher PD within schools and improve student achievement.

CU-TLP proposes a quasi-experimental mixed methods study, designed to meet What Works Clearinghouse (WWC) standards, in pursuit of the following goals:

Overarching Goal
Create replicable CU-TLP Model that identifies and supports personalized professional development pathways (PPDPs) designed to improve STEM teacher effectiveness and student achievement in South Carolina's high-needs, high-poverty middle schools that predominantly serve identified Qualified Opportunity Zones ***(AP1, CPP1-3)***.
Goal 1: Create a recommender system to provide guiding suggestions for human development of personalized professional development pathways (PPDPs) (***AP1.3, CPP3***). [*Evidence-based professional enhancement activities* ***(AP1.3)***]
Goal 2: Customize professional development to align with PPDPs ***(AP1.2, CPP1-3)***. [*Evidence-based PD* ***(AP1.2)****; promoting STEM* ***(CPP1)****; fostering socio-emotional skill development* ***(CPP2)***]
Goal 3: Evaluate CU-TLP's effectiveness ***(AP1.2, CPP1-3)***. [*Evidence-based PD activities* ***(AP1.2)****; promoting STEM* ***(CPP1)*** *and socio-emotional skill development* ***(CPP2)***]

The logic model that supports this proposal can be found in Table 3 of section C.

Previous research shows that effective teacher PD follows several best practices that encourage high value buy-in (Darling-Hammond et al., 2017): (1) PD is content/standards-focused (applicable to classroom content and pedagogies); (2) PD engages participants in learning and modeling (inquiry/constructivism; (3) PD provides coaching and expert support; and (4) PD is sustained in depth and duration. When these evidence-based practices are focused on and linked to individual and school needs, PD becomes personalized learning (Wells, 2014).

A five-year study on STEM middle grades teachers, led by PI Marshall, showed that highly effective STEM PD can narrow the achievement gap for all groups of middle school students while also increasing achievement for all groups. Results further indicated that students in classrooms led by teachers receiving sustained PD support for 1-2 years in duration demonstrated growth on average 6-9 months beyond their peers whose teachers did not receive PD (Marshall & Alston, 2014; Marshall, Smart, & Alston, 2017).

Additionally, work from What Works Clearinghouse (detailed in section B1) indicates that significant changes in professional learning occurred as a result of participation in National Board for Professional Teaching Standards (NBPTS) and Enhancing Missouri's Instructional Networked Teaching Strategies (eMINTS). CU-TLP uses NBPTS Core Propositions to frame advanced credentials but additionally provides a PPDP to guide teacher growth through an iterative continuous improvement process (Cowan & Goldhaber, 2016; Meyers, Molefe, Dhillon, & Zhu, 2015). Further, CU-TLP's Model supports teachers in developing student-centered, inquiry-based learning environments through its PD, similar to what was achieved in eMINTS. Yet our PPDPs also individualize learning based on teacher and school needs. Collectively, CU-TLP furthers the other meritorious PD programs and aligns with the SEED priorities ***(AP1.2-3, CPP1-3)***.

CU-TLP moves away from the common one-size-fits-all approach to a personalized PD system by basing recommended pathways on the needs, interests, abilities, and contexts of teachers and schools, instead of the common approach of pursuing global topics for a given year. CU-TLP proposes using a recommender system algorithm to provide iterative, personalized PD by gathering and analyzing large amounts of data (e.g., student achievement, teacher performance, teacher and school needs) to suggest automated, analytical decision-making aid (Fok & Ip, 2006).

Recommender systems are technologies that provide context-specific recommendations to guide users toward the discovery of preferred content or options (Lu, Wu, Mao, Wang, & Zhang, 2015). Their utility and versatility have made them popular and essential tools in a variety of environments, including ecommerce and online media (e.g., Netflix or Amazon). These systems match users (teachers) with items (PPDP suggestions) that lead to promoting a chosen metric, such as satisfaction or preference (an optimal PD pathway for each STEM teacher). We propose a hybrid recommendation algorithm that combines an "interests and skills"-based algorithm with

a “needs”-based algorithm. The “interests and skills”-based algorithm augments collaborative filtering (the most prominent type of recommendation algorithm, which allows user recommendations to be created based on users with similar preferences and behaviors (Schafer, Frankowski, Herlocker, & Sen, 2007)) with work on “self-actualization” (helping users explore and understand their underdeveloped interests (Knijnenburg, Sivakumar, & Wilkinson)); the “needs”-based algorithm implements a retroactive comparison technique to provide developmental pathways based on past successes. This recommender system design will be optimal for early model iterations as it will allow teachers and PD facilitators to collaboratively improve the system, thus allowing the successes of each cohort to inform the next.

Figure 1 illustrates the proposed CU-TLP PD Model, a significant advancement from the traditional PD approaches. The inner circles represent the core components and phases of the customized PD based on best practices, individual teacher needs and school needs, advanced credentials, and continuous improvement (see section A2). The outer arrows represent the

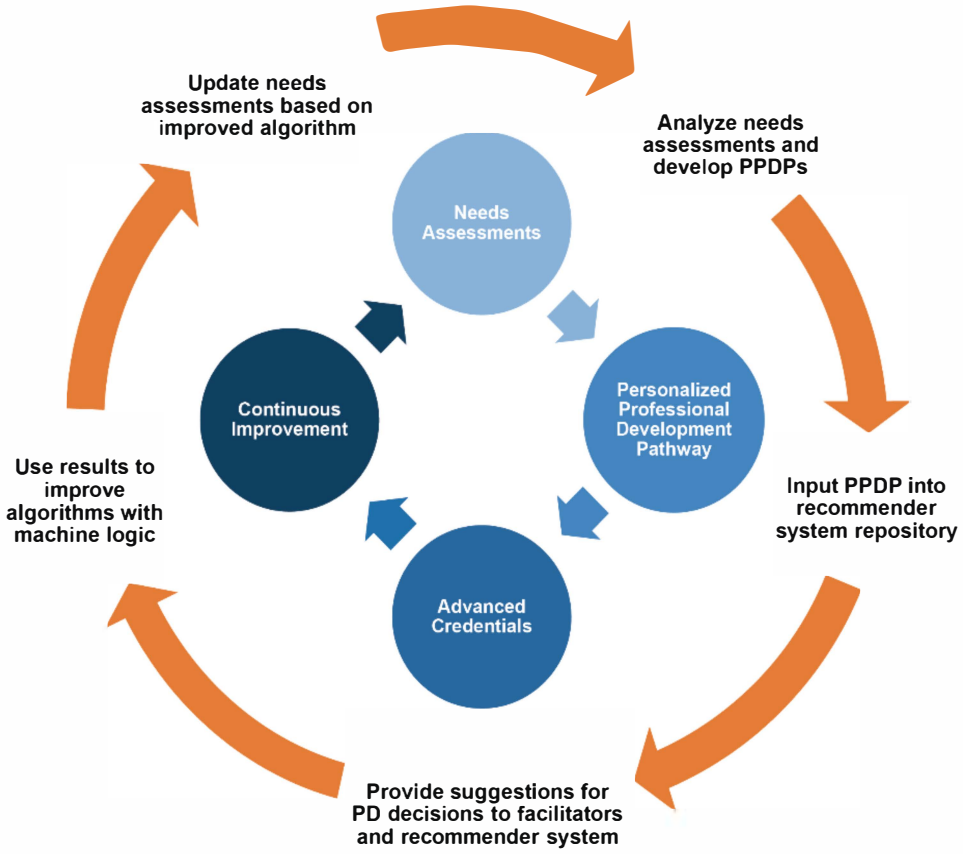

Figure 1: CU-TLP PD Model

iterative process of the recommender system that will be improved by data from real PD experiences and outcomes. Initially, PD facilitators guide the development of the PPDP. By year three, the recommender system will have sufficient data and validated algorithms to assume the main role in determining PPDP outputs. We anticipate that the resulting collaborative filtering algorithmic recommender system, informed by real PD experiences and outcomes, will reduce one-size-fits-all learning experiences, save money in low-income schools, improve teacher engagement and outcomes, and be replicable in multiple settings and disciplines.

CU-TLP will benefit STEM teachers from **16 traditionally underserved local educational agencies (LEAs) in South Carolina *(A1)*** by focusing on personalized **evidence-based PD and enhancement activities *(AP1.2-3)***. These personalized curricula will improve teachers' classroom-based competencies in STEM, including computer science and socio-emotional skill development; prepare them to deliver rigorous instruction in STEM fields; and support their retention in traditionally underserved schools. For schools, the CU-TLP Model provides a more intentional approach for supporting teacher professional growth.

A2. Professional Development Is of Sufficient Quality, Intensity, and Duration

CU-TLP incorporates factors that lead to the largest teacher growth effect sizes. Specifically, we know that creating **safe, respectful, well-organized learning environments** are necessary for success in the classroom, but by themselves they do not lead to significant growth among students (Hattie, 2012). CU-TLP will develop PD in areas where greater variance for growth is likely to be seen (e.g., integrating formative assessments more successfully in STEM classrooms) (Hattie, 2012; Marshall, 2016). Achieving such growth is challenging in under-funded school districts, like those targeted for this intervention, as schools and teachers frequently lack the support and resources necessary to accomplish **systemic and sustainable PD**

planning. The personalized, stackable, advanced credentials are guided by research, indicating where teacher development is most likely to yield the greatest results but also where the needs assessment shows the teacher needs to improve most. Finding the intersection between **research-based practices and teacher needs** is likely to yield the greatest overall success.

CU-TLP's methodical four-phase process framework ensures sufficient duration and intensity. The framework unites STEM teachers, school leaders, and PD facilitators in personalized professional learning and growth with teachers in SC high-needs, high-poverty middle schools. CU-TLP's phases are grounded in best practices and include: Phase 1: **Pre-Assess;** Phase 2: **Plan;** Phase 3: **Do;** and Phase 4: **Continuous Improvement.** Through this work, CU-TLP will focus on improving effectiveness and retention of 527 STEM teachers who will further impact the achievement of over 25,429 middle school students in SC.

Phase 1: Pre-Assess. Foundational work will guide development of each PPDP. Generating effective PPDP recommendations depends on the quality and timeliness of input data to contextualize PD. Initial data collection will include identifying challenges, strengths, needs, and growth targets. A user-centered interface and database will be built for researchers, teachers, school administrators, and district leaders, to enter needs assessment data. Researchers will collect and analyze the needs assessment data to develop algorithms to match the needs of teachers and schools with expected learner outcomes. The needs assessments will provide researchers with local context and will build school-level buy-in for CU-TLP interventions.

Phase 2: Plan. In Phase 2, the PPDP is developed to provide each STEM teacher with a PD pathway to effectively address teacher and student needs in underserved LEAs. Phase 2 has three critical points of buy-in. First, **CU-TLP will be aligned with real needs.** PD facilitators will review and analyze the needs assessments from Phase 1, and CU researchers will develop

recommender system algorithms to help PD facilitators create targeted PPDPs. The PPDPs will recommend an advanced credential pathway designed for continuous professional growth and ongoing development of individual STEM teachers.

Second, **PD facilitators, school leaders, and STEM teachers will enter into a partnership** an explicit commitment to pursue competencies outlined in the PPDP. Each PPDP will be closely integrated with teachers' individual, goals-based evaluation (GBE) plans, which the SC Department of Education requires all SC teachers to update annually. Each GBE goal incorporates student learning objectives and is stated in terms of change or improvement over time. PPDPs will guide GBE plan formation as follows. The school leader meets with the STEM teacher to negotiate PPDP and GBE goals, identify the competencies that will be achieved, and form a contractual plan of action. By linking the PPDP to the GBE, teachers can be assured that time and energy spent improving effectiveness will be integrated into the larger continuous improvement goals negotiated with their administrator. The CU-TLP PPDP, therefore, is an integral part of broader schoolwide and districtwide educational improvement plans, and it encourages greater teacher buy-in since PPDP is aligned to personal and school goals.

Third, **CU-TLP will offer teachers evidence-based PD through a series of stackable advanced credentialing options that will demonstrate teachers' development and mastery of defined instructional competencies and skills**. Teachers will earn credit for micro-credentials (MCs), courses, endorsements, and/or a degree that focus on developing content knowledge, pedagogical proficiencies, socio-emotional skill development, and/or instructional leadership (e.g., mentoring 1-1 adult learners, instructional coaching). Figure 2 lists advanced credential options by topic. Note: only the MCs need to be developed, as courses, endorsements, and program are already in existence. Advanced credentials will be available to other teachers

and schools based on pre-assessed needs and teachers' PPDPs thus allowing the CU-TLP Model to be reproducible and scalable to other districts beyond partner districts for this grant. Curriculum will be designed to maximize teacher effectiveness and student achievement. Participating STEM teachers will commit to pursue at least four targeted MCs, an endorsement, or another course pathway. Each MC provides relevant classroom applications and is equivalent to 8-10 contact hours, thus ensuring at least 32-40 contact hours of PD for four MC pathways.

Content-, Needs-, and Skills-Focused MC Pathways		
Math MCs -Proportional Reasoning -Process Skills and Engaging Learners -Algebra and the 21st Century -Current Technologies in Math Classrooms	**Computer Science MCs** -Computer Science Practices and Impacts -Computing Systems -Networks and the Internet -Algorithms and Programming	**Instructional MCs** -STEM Learning Environments -Overcoming Apathy in High-Poverty Classes -Digital Media and Learning in STEM Classrooms -STEM Instruction: Theory to Practice -STEM for Learners -Discourse in STEM Classrooms -Building Coherent, Connected Classrooms -Creating Creative, Problem-Solving Culture in STEM Classrooms -Interactive, Thoughtful Learning in STEM Classrooms -Highly Effective Instructional Practices
Science MCs -Integrating Scientific Practice and Engineering Design -Science-Specific Technologies in the Classroom -Cross-Cutting Concepts in Science -Science through Inquiry	**Socio-Emotional Skills MCs** -Understanding Socio-Emotional Learning -Fostering Positive Relationships -Developing Students' Self-Regulation and Motivation -Measurement Tools for Socio-Emotional Learning	
Endorsement Pathways		
STEAM Endorsement -STEAM Instructional Design -STEAM Transdisciplinary Teaching -STEAM Assessment -STEAM Enacted and Evaluated	**Teacher Leader Endorsement** -Elements of Instructional Effectiveness -Curriculum, Instruction, Assessment, and Learning from a Mentor Perspective -Critical Issues in Instructional Coaching and School Leadership -Reflective Instructional Coaching Practice	**Online Teaching Endorsement** -Effective Online Teaching -Online Course Management -Web Tools to Enhance Online Engagement -Instructional Design and Assessment
M.Ed. in Teaching and Learning Degree Pathway		
6 core classes studying learning, motivation, assessment, cultural diversity, and classroom-based research, plus 4 classes in chosen specialization area (**STEAM, Instructional Coaching, Online Instruction, or Effective and Reflective Practitioner**)		

Figure 2: Advanced Credential Pathways

Phase 3: Do. In this phase, STEM teachers pursue their PPDP that will provide a significant, though not infinite, array of options. CU-TLP will balance finding what STEM teachers need with what research indicates is likely to result in significant change in teacher effectiveness (e.g., socio-emotional skill development). PD facilitators will be responsible for identifying the recommended balance initially, but as more data are gathered over time from a variety of teachers and PPDPs, the adjustment of this balance will shift to a reliance on a collaborative filtering recommender system with oversight from PD facilitators.

CU-TLP's personalized, stackable, advanced credential options will be designed to increase teacher knowledge and skills, student achievement, and teacher job satisfaction. Stackable credentials pathways range from individual-level professional growth designed to impact individual classrooms, to system-level improvements that seek to effect change through building level leadership. Figure 2 lists possible PD pathways (actual MC offerings and course objectives will be adjusted based on the needs of the population). The MC, course, endorsement, and degree options are portable to other districts across the state for recertification credits, state-level licensure endorsements, and salary schedule step increases. These options are also portable to other states with similar requirements for recertification and salary increases. These options enable talented classroom teachers to build their instructional abilities without having to leave the classroom, benefiting teachers even if they later change districts.

Duration. Depending on the PPDP goals, we expect participants to engage with CU-TLP for at least two years. This supports evidence stating that PD is most effective when sustained over a significant period of time (Supovitz & Turner, 2000). While 100% participation of STEM teachers in each school is ideal, we seek an **average of 80% participation of STEM teachers** within partnering schools. Participation at lower levels will deter a sustainable effort, particularly

when teacher turnover is included. Partnerships will be established first at the district level (see letters of support). At the recommendation of the district superintendent, specific schools will be targeted based on the needs of the school, priorities of the school (e.g., STEM focus), and commitment and support of school leadership. Based on prior PD facilitation experience (Marshall et al., 2017), we expect 60% of the schools within the partnering districts to participate (35 partnering schools) **schools in QOZs will be prioritized**. After school leaders agree to participate, face-to-face and/or virtual recruitment meetings will be held with all STEM-focused teachers to gauge interest in participation (we anticipate 527 participating teachers; see Table 1).

Micro-credentials (MCs): MCs, topical-focused professional learning modules, provide a means for STEM teachers to **improve their content knowledge, instructional practice, and/or socio-emotional skill development** in targeted, engaging ways. MCs will be (1) *personalized,* allowing educators to pursue modules most useful and relevant to them; (2) *as needed,* allowing educators just-in-time support; and (3) *recognized* through digital badges. CU-TLP will develop a series of online MCs that are aligned to PPDP needs.

The structure of each MC follows a similar pattern that includes: (1) a **core essential question** or problem being answered, (2) a **modeling and experiential portion**, (3) **explicit extension to classroom**, and (4) **practice/debrief/challenge**. Completion of each MC will be acknowledged, as will larger MC achievements (digital badges), to be recognized at the silver (4 MCs completed), gold (8 MCs), platinum (12 MCs), and diamond (15 MCs) level. Achieving platinum or diamond levels satisfies SC teachers' five-year continuing education requirements. Completing two courses and attaining the silver level of MCs will also achieve the requirement.

Courses: Some PPDPs will recommend that individual teachers take one or more complete courses to develop leadership competency in areas where MCs alone may not suffice. For

instance, STEM teachers desiring to develop their leadership/mentoring capabilities may opt to take a two-course sequence focusing on deep reflection on their own instructional practice as well as 1-1 mentoring. This sequence helps strengthen the leadership capacity of those who work with student teachers, teacher residents, alternative certification teachers, and/or induction teachers in STEM fields.

Endorsements: Currently available coursework includes three, four-course endorsements recognized by the SC Department of Education (detailed descriptions of endorsements follow).

Endorsements and Descriptions
STEAM (Science, Technology, Engineering, Art, and Mathematics) endorsement provides a transdisciplinary approach for engaging learners to solve real-world problems. This endorsement, the first of its kind in the U.S. that we are aware of, challenges teachers to develop STEAM competencies in creativity, communication, critical thinking, and collaboration—all vital for success in today's workforce. This endorsement prepares teachers to lead in their own classroom as well as to support the development of others in their building—thus increasing leadership capacity in STEAM.
Teacher leader endorsement has students develop an understanding of professional learning, coaching models, student-centered collaborative protocols, and student-centered instructional and coaching practices. This endorsement will help to develop the capacity to lead PD within the school, so CU-TLP Team will serve as the PD specialist until school capacity is developed. CU's temporary liaison role will shift to greater and greater school ownership as STEM PD leadership capacity is developed.
Online teaching endorsement utilizes learning sciences principles to address foundational concepts such as instructional design/development, strategies to enhance engagement and cognition, and effectively collecting/analyzing data needed to evaluate the learning and performance of individuals, programs, and organizations.

Degree: Teachers seeking a degree can pursue the M.Ed. in Teaching and Learning from Clemson University College of Education, currently ranked as the **number one online graduate education program** in the nation for the fourth consecutive year by U.S. News and World Report (U.S. News and World Report, 2020). The M.Ed. provides yet another avenue to encourage the retention and development of STEM teachers. Degree-seeking students may also earn an endorsement in STEM, teacher leader, or online teaching.

Phase 4: Continuous Improvement. Learning is a formative process. Part of this continual growth process requires school leaders and STEM teachers to revisit their GBE annually to ensure teachers are advancing toward their targets. Student achievement measures will be gathered during Phases 3 and 4. Many STEM teachers will likely realize they have other areas needing further development based on insights gained and interests identified during advanced credential PD or PPDP feedback. The CU-TLP Team will support the transition from relying on facilitator and liaison support towards increased PD leadership roles in the school. Schools will always need outside PD assistance, but they will also become more able to internally support PD as teachers develop competencies, mentor new or induction teachers, and/or provide instructional leadership to peers.

A3. Appropriate to and Will Address Needs of the Target Population

Billions of dollars are invested annually for PD in the U.S., with mixed results. CU-TLP can help practitioners and policymakers distinguish between effective and ineffective PD by aligning with evidence-based research validating that effective PD: (1) is content/standards focused, (2) engages participants in learning/modeling, (3) provides sufficient supports/coaching, and (4) is sustained over time (Darling-Hammond et al., 2017). Additionally, this proposal incorporates a needs-based approach that extends beyond district-level mandates, seeks buy-in from both the school and teacher participants, includes high-needs schools, and is led by a CU-TLP Team with a demonstrated record of PD success.

State context: Education in SC is at a crucial juncture. Persistent poverty continues to be a challenge throughout the state. In 2018-19, 61.9% of SC public school students (vs. 47.3% nationally) qualified for free and reduced lunch (National Center for Education Statistics, 2019). How we recruit, foster, and retain effective STEM teachers in high-poverty schools must take

center stage in research and policymaking efforts. Without profession-ready teachers, our students particularly students in high-needs, high-poverty, under-resourced schools are deprived of the educational learning experiences needed to prepare them to be successful adults in an ever-changing economic landscape. Receiving a highly-effective education is a cornerstone to economic prosperity good jobs, better quality of life, and increase in civic engagement.

Teacher retention. In Fall 2019, 556 teaching positions went unfilled in SC schools (Center for Educator Recruitment Retention & Advancement [CERRA], 2019). Further, 6,650 teachers did not return to their district last year. A majority of these vacancies have occurred and will continue to occur in high-poverty, high-needs settings. For teachers hired for the 2018-19 school year, 28% did not return or moved to a teaching position in another SC school district (CERRA, 2019). Poor retention and instability remain persistent issues.

Teacher effectiveness. Teacher effectiveness is one of the greatest school factors influencing student success (Hattie, 2012). Yet there remains a persistent disparity in the U.S. between family income and student achievement (Isenberg et al., 2016). Specifically, disadvantaged students tend to have less effective teachers than their more advantaged peers (Max & Glazerman, 2014). For SC, poverty index data reported by the SC Department of Education in accordance with the state's Education Finance Act is somber. The average poverty index for school districts in the state was at 61.7% in 2019 (69.1% for partnering districts) (South Carolina Department of Education, 2020a). CU-TLP is designed to investigate the degree to which a systemic PD effort can begin to reverse historic inequities.

Student achievement. Forty-four percent of SC students reported an interest in STEM career fields (ACT, 2018). Despite this interest, **SC students lag behind their peers in other states in their readiness to pursue advanced STEM education.** Specifically, only 25% of

students in SC (vs. 41% nationally) are ACT Math College Ready,[1] and only 23% (vs. 37% nationally) are ACT Science College Ready (ACT, 2018). National Assessment of Educational Progress (NAEP) scores show only 26% of SC 8th graders being proficient in mathematics and 31% in science (Institute of Education Sciences, 2017). Proficiency drops significantly in both math and science from 4th grade to 8th grade thus another reason to focus on middle grades.

Responding to the need. SC must address critical gaps in access to high-quality teachers and in student achievement in the poorest school districts in order to be responsive to evolving demands for a well-prepared, diverse, and competitive STEM workforce. CU-TLP can begin to meet this call by providing educators with **PPDPs** designed to increase: (1) teacher retention rates, (2) teacher effectiveness, and (3) student achievement.

School district partnerships. CU-TLP will partner with 35 middle schools in 16 high-needs SC school districts. Table 1 provides a profile of each district's middle schools. Twelve of the 16 partnering districts have attendance zones within the Qualified Opportunity Zones (QOZs) (see Appendix G for listing of QOZs tied to participating district attendance zones ***(CPP3)***). This profile highlights the urgent need to recruit, support, and retain high-quality teachers. We have an extensive and ongoing partnership with 13 of the 16 proposed districts for this grant (e.g., Teacher Residency and Principal Leadership Development). We have been exploring collaborative opportunities with the other 3 districts for more than two years.

Implementing CU-TLP partnerships in 16 districts results in 1,098 possible middle school STEM teachers. We project, based on prior experience leading PD, that 60% of schools will participate from each district, with an average of 80% participation of STEM teachers from those schools (schools in QOZs will be prioritized). Further, we expect 80% of all first-year

[1] "Ready" determined by benchmark score where at least 75% of students would likely earn a C or higher in first-year college courses.

participants will continue for a second year of participation. This results in projected participation from 527 STEM teachers (198 year 1, a total of 304 in year 2, and 298 in year 3). The remaining 571 non-participants will be part of the data comparison group. The participant and non-participant groups far exceed the number for sufficient power (see section D1) and will further allow complex modeling scenarios to be performed. Partnership agreements with schools will be structured to require support from school leadership and participation in CU-TLP from at least 60% of the STEM teachers in each school.

Table 1. Profile of Middle Schools in Partnering Districts (2019 Data)

		Total # Possible			Average		% Meets/ Exceeds Grd 8 Standards		
District	**Phase**	**Grd 6-8 Students**	**STEM Teachers**	**Middle Schools**	**Poverty Index***	**FRL****	**ELA**	**Math**	**Science**
Greenville	1	16,896	413	19	56.8	50.4	48.0	39.9	51.5
Anderson1	2	2,421	57	3	50.0	52.9	56.8	54.9	56.3
Anderson3	2	617	15	1	71.6	57.6	45.8	48.0	46.9
Anderson4	2	418	13	1	62.3	44.7	69.7	49.2	65.9
Anderson5	2	3,015	82	4	61.0	58.5	52.6	50.7	49.2
Oconee	2	2,417	67	3	63.9	52.0	46.1	44.7	48.7
Pickens	2	3,737	89	5	59.4	49.7	47.5	40.7	50.6
Florence1	3	2,494	65	3	65.5	56.7	44.3	25.9	49.8
Florence3	3	634	17	2	86.2	100.0	37.3	22.0	39.6
Grnwood50	3	2,070	49	3	72.6	72.7	35.9	33.0	54.0
Grnwood51	3	283	8	1	76.7	65.5	38.1	54.0	33.3
Grnwood52	3	385	8	1	60.6	51.7	47.4	17.2	48.3
Laurens55	3	800	20	2	73.1	78.5	31.2	27.3	33.5
Laurens56	3	710	18	1	80.3	100.0	36.6	17.6	33.3
McCormick	3	170	4	1	84.0	nd	29.5	20.5	20.5
Richland1	3	5,314	173	9	81.6	100.0	33.8	19.4	30.5
Total Possible		42,381	1098	59	69.1	66.1	43.8	35.3	44.5
Projected # Participants		25,429	527	35					

*Poverty Index—Percentage of students who are transient, in foster care, homeless, or have been Medicaid-eligible or qualified for SNAP or TANF services within the last three years [Education Finance Act (EFA)]
**Free and Reduced Lunch (FRL) Rate (2016)

STEM teachers. CU-TLP will provide middle school STEM teachers in the 16 participating districts with opportunities to develop instructional leadership skills that can be

used in their classrooms, also boosting the instructional capacity of the school as a whole. The MCs focus on PD improvements that target individual teacher needs. Endorsements and degree options provide an advanced level of preparation, so teachers can begin to lead and mentor others in their building in addition to thriving in their own classroom.

School leaders. The school principal's impact on student achievement is second only in importance to that of the classroom teacher. Schools most able to improve student achievement are those that have effective school leaders (Louis et al., 2010). The school leader's influence on student achievement is indirect and mediated by instructional and transformational leadership practices, creating a school environment necessary for effective teaching and learning to occur (Robinson, Lloyd, & Rowe, 2008). Principals will play a role in identifying school/district needs, encouraging STEM teacher participation, and negotiating and supporting PPDPs that are linked to teachers' annual goals-based evaluations (GBEs). The activities will support the long-term effort of developing STEM teachers in a sustained manner. The expectation is that STEM teacher participants will remain in the school/district and become part of its ongoing sustainability plan.

A4. Potential and Planning for Work to Extend Beyond End of Grant

SEED funding will provide the support necessary to develop the replicable CU-TLP Model that will provide PPDPs that guide teacher effectiveness development. PPDPs will be informed by the recommender system. SEED funding will allow a more systemic effort to be undertaken that allows a reproducible approach to PD with partnering and new districts across the state and region (see section B3, Dissemination of Project Results).

Beyond the grant award, the CU's College of Education is committed to CU-TLP, as demonstrated by dedicated capacity and funds to the project. Endowment funds from the Moore School of Education, used as part of the matching requirement, will help to ensure that funding

support continues beyond the period of federal grant funding. Also, we will continue to seek public and private support of this project (e.g., Clemson University Foundation). Table 2 outlines the sustainability plan for future development and continued funding. In addition, economies of scale solutions may be implemented that reduce overall institutional costs by identifying resources and services that are in wide demand. Costs will go down as SEED funding underwrites the start-up costs of developmental activities, needs assessments, MCs, the recommender system, etc.

Table 2: CU-TLP Sustainability Plan

Sustainability Factor	Activities (Timeline)
Collaborations -Sustain existing partnerships -Develop new partnerships -Develop partnerships with other PD providers	1. Continue work with **existing partners** (ongoing) 2. **Expand program** to other high-needs districts (ongoing) 3. **Collaborate with other PD providers** to share CU-TLP Model (yr 4) 4. **Collaborate with districts** to use state/federal PD monies to support (beginning yr 4)
Resources -Share CU-TLP Model -Share recommender algorithm -Share, refine, and provide advanced credentials	1. **Share CU-TLP Model** with districts and PD providers (yr 4) 2. **Share recommender system and algorithm** (yr 3) 3. **Share** MCs, PPDPs, and measures (beginning yr 4) 4. **Revise advanced credentials** based on feedback and needs (ongoing beginning yr 2) 5. **Continue teaching courses** associated with endorsements and degrees (ongoing beginning yr 1)
Financial and Scale-Up Strategies -Seek additional funding -Expand types of funding	1. Seek **SC Department of Education** endorsement of program (yr 4) 2. Seek additional **state** (e.g., Center of Excellence) **and federal grant** (e.g., NSF) support for CU-TLP Model and program (ongoing beginning yr 3) 3. Approach **industry partners** for financial support (ongoing) 4. Solicit private donations from **alumni and foundations** (ongoing)

Regarding scalability of the program, the concepts underlying the CU-TLP Model are applicable to all major PD efforts and include: (1) the systemic model (human and recommender system); (2) MCs, courses, endorsements, and degree; (3) stackable credential framework; (4) school and teacher needs assessments to guide PD decisions; and (5) PPDP outputs.

B. SIGNIFICANCE

B1. Importance or Magnitude of the Results or Outcomes Likely to be Attained

Improvements in teaching and student achievement. CU-TLP's replicable Model will support PPDPs designed to improve STEM teacher effectiveness and student achievement in SC's high-needs, high-poverty middle schools. The model draws upon two studies, summarized below, found in What Works Clearinghouse (WWC) for guidance in developing PD pathways for teachers ***(AP 1.2-3, CPP1-3)*** (Cowan & Goldhaber, 2016; Meyers et al., 2015). Based on past studies that have met, with or without reservations, the WWC standards, we expect positive, statistically significant results in teacher effectiveness and student achievement as we work with 527 STEM middle school teachers across 16 districts that serve 25,429 students in high-needs, high-poverty schools. The use of the recommender system algorithm to guide and develop PPDPs and the use of advanced credentials to scaffold STEM PD sets CU-TLP apart from prior PD efforts. CU-TLP will contribute to the greater PD community across the nation by developing a replicable framework that can be shared in entirety or in part (e.g., needs assessments, recommender system algorithm, PPDPs, advanced credentials).

The effects of NBPTS certified teachers on student achievement in mathematics and English is one of five studies using a quasi-experimental design that meets WWC group design standards with reservations, which is included in the 2018 WWC Intervention Report, *NBPTS Certification* (Cowan & Goldhaber, 2016). NBPTS aligns well with CU-TLP because the M.Ed. in Teaching and Learning coursework (all specialization areas) is framed by NBPTS standards. Results showed a statistically significant, positive effect on NBPTS student achievement in mathematics (n 110,634). Specifically, student achievement data of elementary and middle school NBPTS teachers were compared with student achievement data from non-National Board Certified teachers. NBPTS teachers had previously demonstrated strong content knowledge and teaching

practices, ability to differentiate instruction and establish a conducive and effective learning environment, and reflective practices. Further, courses such as the first course in instructional coaching specialization use the Core Propositions of NBPTS to encourage teachers to reflect deeply on their own teaching while seeking evidence in their practice that supports/models highly effective teaching (see Figure 2 for a list of proposed advanced credentials).

The eMINTS program implemented in 60 rural Missouri schools supported teachers in developing student-centered, inquiry-based, technology-rich instructional practices (Meyers et al., 2015). Findings show statistically significant effects on quality of teachers' lesson designs, teachers' use of inquiry-based learning strategies, and student achievement in mathematics. Teachers in the eMINTS program received sustained PD, feedback on quality of lessons, focused standards comprehension, data analysis, and inquiry-based instruction.

Applying the WWC findings to CU-TLP. CU-TLP teachers will likewise focus on sustained PD that engages teachers in learning that focuses on the same topics as the eMINTS program and that aligns with NBPTS: teacher content knowledge; student-centered, inquiry-based instructional practices; methods for differentiation of instruction; socio-emotional skills; and focused and reflective conversations with cohorts of their peers. A clear benefit of CU-TLP is that professional learning will be based on their PPDPs as they pursue advanced credential options. Because teachers' professional learning will utilize the research-based practices mentioned above, increased student achievement is expected. Further, CU-TLP will extend what is known about extensive, sustained PD experiences that can be replicated to provide a more iterative support design. Collectively, the magnitude of CU-TLP will be profound for the 527 STEM teacher participants and their 25,429 students. The integration of a recommender system

to guide and personalize PPDPs and the use of advanced credentials to scaffold STEM PD sets CU-TLP apart from prior PD efforts.

Fiscal savings. The costs of a public education are real, but so are the long-term savings when efforts are made to keep students in school and/or attend college. For each student that we get back on track to graduate from high school, it is estimated to save taxpayers approximately $13,950 per year or more than $230,000 over a lifetime in welfare payments, food stamps, criminal justice, and/or medical costs (Belfield, Levin, & Rosen, 2012). Additionally, the cost to replace teachers in the U.S. is estimated to be as high as $2.2 billion per year. In SC, the cost of replacing one teacher is approximately $20,000 (Haynes, 2014). If the proposed project can prevent 10% of the teachers from leaving the profession in the near term, that alone would save over $1 Million (54 teachers × $20,000) and will help us reduce the high number of classrooms that begin the year without a qualified teacher (over 550 this past year alone).

Collectively, project costs are nominal when considering the research value, the value in raising student achievement, and the value in providing better prepared teachers and instructional leaders in STEM classrooms who stay in teaching longer than their peers.

B2. Potential Contribution of Project to Development and Advancement of Field

CU-TLP's Model will provide opportunities to advance theory, knowledge, and educational practice. Replication in part or in whole (needs assessments, recommender system algorithm, PPDPs, advanced credentials, and teacher/student data) provides enormous opportunities to advance the field in how we develop, lead, and facilitate personalized PD.

Advancing theory and knowledge. Collectively, the CU-TLP Model represents a unique approach to how we conceptualize and facilitate *personalizing* PD. The holistic model focuses on teacher and school needs, utilizes a data- and algorithm-driven recommender system to generate

PPDPs, provides options for advanced credential pathways, and is designed and refined based on needs and best-practice for PD. CU-TLP will allow us to better understand the relationship between personalized PD, teacher learning, teacher effectiveness, and student achievement for STEM teachers and their students. The evaluation of CU-TLP will provide important insights into the effects for teaching and learning in SC's middle schools with a focus on high-needs, high-poverty schools.

Education research has focused for years on personalized (differentiated) instruction for students (Tomlinson, 2014), but less attention has been directed toward personalized PD for teachers (adult learners). Aided by a data- and algorithm-driven recommender system, the results of CU-TLP will generate insights to inform future, ongoing research in this area. We anticipate that our PD work will help to advance what are seen as best practices in PD. This may include understanding how the amount of PD experiences, the duration, the order of coursework, and topics effect teaching effectiveness and student achievement. In school learning environments altered by COVID-19 (and continuing uncertainty), CU-TLP is positioned to identify, track, and respond to shifts in demands expressed by teachers dealing with new challenges (see Appendix H). Through a collaboration with computer scientists and school districts, the project includes developing and testing a recommender system for human capital development (i.e., for teachers), which may also have applications in other professional fields and industries.

Advancing educational practice. Clemson University's accredited teacher preparation programs have and continue to demonstrate enormous success with pre-service teachers. For the past three years, our teacher preparation programs have shown a 99.2% pass rate on PRAXIS II. To further advance the quality of teacher education, we began the state's first Teacher Residency program 4 years ago. This bachelor's to master's program includes an entire year of teacher

residency during year 5. The program has experienced dramatic growth (72 new students entering Fall 2020). The additional preparation builds confidence and advances capabilities which allows greater success in more challenging settings thus promoting greater retention.

We recognize, as an education college at a land grant institution, our ongoing responsibilities to support teachers, school districts, and communities, to advance educational practice and address these challenges. As such, we began a college-led induction program (*Perfecting Your Roar*) to provide additional supports for all state teachers during their first two years. We also now have articulation agreements with high schools and technical colleges (*Expressway to Tigertown*) to assist in creating new pathways for prospective teachers. Additionally, we recently launched the Center for the Recruitment and Retention of Diverse Educators, focused on establishing partnerships with school districts throughout the state to identify and address barriers to teacher recruitment and retention. CU-TLP, with its focus on personalized professional development for in-service middle school STEM teachers at various career stages, will complement these and other initiatives, will be scalable to other SC districts and grades, and will be replicable in other state contexts.

Our college has and continues to demonstrate both the quality and expertise needed to lead major initiatives. This leadership was especially clear during our recent COVID challenges where all instruction had to transition online. Not only did we lead and support other colleges in this effort, but it became abundantly clear, as we have spoken to deans from other colleges of education, that we were in many cases far ahead of our peer universities in addressing this challenge. Many of our instructors who successfully managed challenges during COVID-19 will be responsible for developing and leading the advanced credential offerings (see Appendix H).

B3. Dissemination of Project Results for Broader Use by Others

The CU-TLP Model includes teacher and school needs assessments, recommender system algorithm, PPDP outputs, advanced online credentials, and research findings. All except the advanced credentials will be made freely available through publications, the project website, and conferences. Fee for service will be established for facilitating advanced online credentials and/or assisting districts to tailor CU-TLP Model to their specific needs. Project outputs will be shared to: (1) **increase awareness** of the Model and findings among the education and computer science research communities; (2) **increase understanding** among those who will benefit most from the findings and outputs (district and school instructional leaders and/or PD providers); and (3) **increase action** as states, districts, schools, and teachers seek to apply the findings and outputs to their own practice and school setting.

Dissemination by the research team will occur through: **general dissemination** of outputs and research findings (*academic journals,*[2] *conference presentations,*[3] *newsletters, social media, media spotlights, and published annual reports*); **online dissemination** to broadcast outcomes and advanced credentials; and **events** such as live and pre-recorded webinars and workshops. Further, to increase visibility and access, project outputs will be uploaded to online open access outlets such as ResearchGate (researchgate.net) and Figshare (figshare.com).

Finally, we will work with our Advisory Board, particularly Anne Pressley from the SC Department of Education, to share project outcomes, including opportunities to scale the project with state education leaders (see Table 2 Financial and Scale Up Strategies). We will also reach out to the SC Opportunity Fund to increase their awareness of our project's activities and

[2] E.g., Teaching and Teacher Education, Journal of Research in Science Teaching, ACM journals on intelligent systems and information sciences
[3] E.g., American Educational Research Association, National Council for Teachers of Mathematics, ACM conference on Intelligent User Interfaces

outcomes relevant to QOZs. Improving teacher retention, teacher effectiveness, and student achievement in STEM in QOZs could be attractive to investors interested in economic revitalization in these areas.

C. QUALITY OF MANAGEMENT PLAN

Table 3 provides a logic model for the overall project structure. The evaluation plan detailed in section D includes the evaluation questions and data sources that are aligned to the logic model objectives, measures, and outcomes detailed below. **Appendix H addresses how we will address COVID-19 challenges surrounding this project.**

Table 3: Logic Model for CU-TLP

Overarching Goal	Create replicable CU-TLP Model that identifies and supports personalized professional development pathways (PPDPs) designed to improve STEM teacher effectiveness and student achievement.		
Context	High-poverty and high-needs SC middle schools Shortage of highly effective STEM teachers Low academic achievement of SC students in STEM		
Rationale/ Approach	CU-TLP Model needed to identify and support growth of middle school STEM teachers.		
Goals	**Goal 1:** Create a recommender system to provide guiding suggestions for human development of PPDPs ***(AP1.3, CPP3)***. **Goal 2:** Customize professional development to align with PPDPs ***(AP1.2, CPP1-3)***. **Goal 3:** Evaluate CU-TLP's effectiveness ***(AP1.2, CPP1-3)***.		
Inputs	**Infrastructure and Capacity: CU** -College of Education / College of Engineering -Clemson Online | Quality Matters -IT Infrastructure -Resources (assessments, curriculum, rubrics, CU-TLP recommender system) -Matching funds	**Collaborative Team:** **CU faculty** -Experienced PD Facilitators -CU-TLP Model Developers **School Partners** -STEM Teachers -School/District Leaders **Trained Classroom Observers**	**External Partners** -WestEd -NWEA -Advisory Board
Activities	**Program Management** -Formalize partnerships -Initiate observer training -Hold project team meetings **Phase 1: Pre-Assess and Phase 2: Plan** -Identify needs/assets of school and STEM teachers -Develop PPDPs informed by recommender system -Develop stackable advanced credential options -Align PPDP with GBE and recommend PPDPs	**Phase 3: Do** -Implement PPDP -Facilitate advanced credentials **Phase 4: Continuous Improvement** -Gather continuous improvement data -Evaluate effectiveness of CU-TLP Model -Refine Model based on evaluation -Share results and findings	

Outputs	-CU-TLP recommender system and PPDP -Repository of PPDP supports and coursework -Expanded network of partners -Outreach/Dissemination (publications, presentations, webinars, etc.)	-Data sources (e.g., assessments, observation data, memoranda of understanding) -CU-TLP Model implemented, replicated, disseminated across state
Outcomes	1. Identified needs (short-term) 2. Improved personalized PD enhanced by iterative recommender system (intermediate/long-term) 3. Increased teacher effectiveness (intermediate) 4. Improved student achievement in STEM disciplines, including computer science (intermediate/long-term) 5. Increased teacher retention (long-term)	

C1. Goals and Objectives Are Specified, Aligned, and Measured

The CU-TLP Model is cohesively structured to align the SEED priorities, goals, objectives, measures, outcomes, and evaluation plan. Table 4 lists the specific objectives associated with each of the three project goals. For each objective, outcomes are specified with corresponding measures. Table 7 (section D3) further aligns the project goals and objectives with specific evaluation questions, performance measures, and data sources.

Table 4: Alignment of Goals and Objectives with Outcomes and Measures

Overarching Project Goal: Create replicable CU-TLP Model that identifies and supports personalized professional development pathways designed to improve STEM teacher effectiveness and student achievement in South Carolina's high-needs, high-poverty middle schools that predominantly serve identified Qualified Opportunity Zones ***(AP1, CPP1-3)***.	
Goal 1: Create a recommender system to provide guiding suggestions for human development of personalized professional development pathways (PPDPs) ***(AP1.3, CPP3)***	
Objective	Outcomes, *Measures*
Obj. 1.1: Assess needs of STEM teachers/schools	527 teachers and school/district leaders in 16 districts will complete needs assessment to inform creation and refinement of PPDPs. ***M1.1:*** *Iterative design/refinement of school and teacher needs assessments*
Obj. 1.2: Develop and implement recommender system algorithm	527 teachers provided with PPDPs to guide advanced credential pursuits. ***M1.2a:*** *Recommender algorithm developed and piloted;* ***M1.2b:*** *Iterative development/refinement of PPDPs;* ***M1.2c:*** *Focus groups studying effectiveness/appropriateness of recommendations*
Obj. 1.3: Establish growth targets for STEM teachers	Growth targets for all teachers aligned to needs assessment data from teacher and school. ***M1.3:*** *Post-hoc analysis of growth target alignment with PPDPs*
Obj. 1.4: Assess effectiveness of	At least 75% of PPDPs will be followed by teachers.

recommender system in establishing PPDPs for teachers	***M1.4a:*** *Interviews with teacher participants, school leaders, and district leaders;* ***M1.4b:*** *Comparison of human decision output vs. recommender system output*
Goal 2: Customize professional development to align with PPDPs ***(AP1.2, CPP1-3)***.	
Objective	Outcomes, *Measures*
Obj. 2.1: Use PPDPs to guide advanced credential offerings	Approximately 26 micro-credentials developed and refined; 12 courses, 3 endorsements, and 1 degree program refined (see Figure 2). ***M2.1:*** *Relationship between PPDPs and credentials attained—modified based on needs and interests expressed*
Obj. 2.2: Develop and implement stackable, certified, advanced credential options to support growth of STEM teachers	At least 90% of 26 micro-credentials, 12 courses, 3 endorsements, and 1 program certified using Quality Matters by end of year 3. ***M2.2a:*** *Iterative development/refinement.* ***M2.2b:*** *Quality Matters certified credential offerings; number and topic of MCs and courses will be modified based on need*
Goal 3: Evaluate CU-TLP's effectiveness ***(AP1.2, CPP1-3)***.	
Objective	Outcomes, *Measures*
Obj. 3.1: Increase STEM teacher effectiveness	Significant increase in effectiveness of STEM teachers by year 2 of participation. ***M3.1a:*** *Classroom observations using SC Teaching Standards 4.0 rubric and focus groups (formative);* ***M3.1b:*** *SC Ready mathematics VAM (summative)*
Obj. 3.2: Improve retention of STEM teachers	At least 90% retention of effective STEM teachers. ***M3.2:*** *Teacher retention data of participants vs. non-participants (summative)*
Obj. 3.3: Increase student achievement in STEM classrooms	Higher rates of growth for students of participating teachers than those for students of non-participating teachers. ***M3.3a:*** *Student performance on SC Ready;* ***M3.3b:*** *Virtual comparisons groups using fall/spring MAP scores;* ***M3.3c:*** *SLOs (student learning objectives) data for computer science teacher participants (formative)*

C2. Management Plan Is Adequate to Achieve the Objectives On Time and Within Budget

Uniting STEM teachers, school leaders, and the CU team of facilitators allows instructional leadership capacity to be developed in underserved LEAs.

Clemson University. Clemson's College of Education has a history of excellence and partnerships with state public schools. The department's award-winning programs will be linked with newly developed MCs to provide a stackable, personalized approach. Clemson Online, CU's large online tech support and development group, has been a powerful contributor to our success

and will support CU-TLP (see section C3 for details). The M.Ed. in Teaching and Learning achieved #1 in the nation through collaborations with Clemson Online and with continual growth and revisions to program quality. Specifically, all faculty teaching in the program engage in at least 18 hours/year of PD, centering on personal and programmatic improvement.

Clemson University CU-TLP Team. While some individuals will serve more than one role, the program management team, led by the PI, will work with our external evaluators, the advisory board, school leaders, and participating STEM teachers to ensure that all portions of the program are well coordinated, all data are gathered, and all programing is provided. Table 5 details specific roles, qualifications, and responsibilities of team members.

Table 5: Roles, Qualifications, and Responsibilities

Principal Investigator: [redacted]
[redacted]. His science education background and success as PI on numerous state and federal grants focusing on highly effective professional development position him well to lead this team. He will meet regularly with the project team, project manager, review board, and external evaluators to ensure compliance in meeting regulations and institutional policy and oversee research, evaluation teams, and data analysis.
Program Manager: ***TBD***
Work directly with PI and Co-PIs to coordinate day-to-day operational duties and to achieve goals and objectives. Supports STEM Teacher Interactions team: acts as liaison between CU and schools, coordinates meetings with schools/teachers, and assists Dr. Rapa in gathering needs assessments.
School/District Partnerships: [redacted]
[redacted] has research expertise focusing on superintendency and district partnerships. [redacted] is a retired school superintendent with strong district and state ties. [redacted] works on developing rural school leadership capacity in SC and internationally. Together, they will work to develop MOUs with districts and schools to ensure strong partnership among CU, district, and schools.
STEM Teacher Interactions: [redacted]
[redacted], comes from a STEM background and has worked closely with a consortium involving seven of the partnering districts. [redacted] works daily with partnering districts on pre-service and in-service supports. They will develop and maintain teacher partnerships within identified schools and train observers for classroom observations. [redacted] will oversee

development, pilot, revision, and implementation of the needs assessment and will coordinate data integration with the recommender system.

Recommender System: [redacted]

[redacted] They will lead the development of the recommender system and organize/lead development of the required databases and interfaces associated with the recommender system.

Advanced Credentials: [redacted]

[redacted] has extensive experience in developing and teaching STEAM and technology-enabled courses. [redacted] co-developed the first fully online 4-course STEAM endorsement in the U.S [redacted] has extensive experience developing online courses and programs. They will work with the instructional team to oversee the development and credentialing of advanced credentials to align with Quality Matters standards.

Credential Instructional Team: [redacted]

Evaluation Team: ***WestEd***

[redacted] Oversee project evaluation as outlined in section D.

CU-TLP Advisory Board

[redacted]

Two rotating instructional leader members from cohort districts.

Meets bi-annually year 1-3, oversees CU-TLP strategy and annual operating plan, and provides strategic advice to the PI and Co-PIs (convened by Dr. Marshall).

Classroom observers. CU-TLP classroom observers will contribute to the formative development of STEM teacher leader participants. CU-TLP observers will be recruited from the region where the participants are located and will be trained in using the South Carolina Teaching Standards 4.0 (SCTS) rubric (South Carolina Department of Education, 2020b), the state's primary teacher evaluation rubric. SCTS 4.0 is designed and validated based on the National Institute for Excellence in Teaching (NIET) performance standards for what classroom-based teachers are to know and be able to do. Previous studies have shown positive correlations

between the NIET teacher observation scores and student achievement as measured by classroom value-added (CVA) scores (Barnett, Rinthapol, & Hudgens, 2014).

Observers will participate in two days of training and standardization to ensure they are well prepared to provide valid assessments. All CU-TLP observers will be required to re-standardize each year of involvement. The two-day training will be face-to-face, with follow-ups online or hybrid in format. Because of grant funding timing, the first group will be prepared during Fall 2020. These individuals will help with building level support and will be responsible for gathering classroom observation data of STEM teacher participants.

CU-TLP data recommender system. The CU-TLP data recommender system is comprised of four key components: **collaborative web interface, databases, web server, and backend recommender system services.** CU-TLP data scientists will develop the first three during year 1. Backend recommender system services that seek to collect and integrate the input parameters to provide optimal recommendation of PPDPs will be started in year 2. All four components are discussed in greater detail in Appendix I.

Timeline and milestones: The timeline in Table 6 shows when CU-TLP activities will take place, including milestones aligned with objectives, target dates, and the team responsible. The management plan allows sufficient time for planning, implementation, and refinement based on ongoing formative assessment. The web interface, databases, and web server associated with CU-TLP will be developed during the first six months of the project. The recommender system algorithm will be created and piloted during year 2. The first evaluation and validation of the system output will occur during year 3.

Table 6: Timeline and Milestones

Milestone/Activity (Objective)	Timeline	Team Responsible
Recruit schools, including MOU (all)	Fall ’20, Spr ’21, Spr ’22	School/District Partnerships
Recruit teachers from participating schools (all)	Fall ’20, Spr ’21, Spr ’22	STEM Teacher Interactions
Develop/pilot school and teacher needs assessments (1.1)	Fall ’20	STEM Teacher Interactions and Project Manager (PM)
Collect needs assessment data from cohort 1, 2, and 3 participants (1.1)	Fall ’20, Spr ’21, Spr ’22	STEM Teacher Interactions and PM
Develop, pilot, refine recommender algorithm (1.2)	Develop Fall ’20, refine throughout	Recommender System, STEM Teacher Interactions, PI
Conduct teacher and leader interviews (1.1, 1.3, 1.4, 2.2, 3.1)	Spr ’21, Spr ’22, Spr ’23	WestEd Evaluation Team
Administer teacher and leader surveys (1.1, 1.3, 1.4, 2.2, 3.1)	Baseline for each group and annually thereafter	WestEd Evaluation Team
Conduct interviews with PD facilitators, CU researchers, and project leadership (1.1, 1.2, 1.4, 2.1, 2.2)	Fall ’20, Spr ’21, Spr ’22	WestEd Evaluation Team
Produce/share teacher PPDPs (1.2)	Fall ’20, Spr ’21, Spr ’22	Recommender System, STEM Teacher Interactions
Gather post-hoc growth targets (1.3)	Summer ’21,’22, ’23	NWEA,ePI
Align PPDPs with teacher actions (1.4)	Spr ’21 throughout	PM, STEM Teacher Interactions
Determine credential offerings (2.1)	Fall ’20, Spr ’21, Spr ’22	Advanced Credentials, PM
Develop credential offerings (2.2)	Fall ’20 entire project	Advanced Credentials, Instructors
Certify credential offerings (2.2)	Fall ’20 throughout	Advanced Credentials
Schedule timing of MCs ad courses (2.2)	Spr ’21 throughout	Advanced Credentials, PM
Teach MCs and courses (2.2)	Each Fall, Spring, Summer starting Spr ‘21	Instructors
Award badges and endorsements (2.2)	Fall ’21 throughout	PM, Student Services
Train classroom observation reviewers (3.1)	Fall ’20, Spr ’21, Fall ’21, Fall ’22	STEM Teacher Interactions
Collect/analyze observation data (3.1)	Spr ’21 throughout	STEM Teacher Interactions, PI
Collect/analyze SC Ready and SCPASS data (3.1 and 3.3)	Each Spring	WestEd Evaluation Team
Gather teacher retention data (3.2)	Each Fall	PM, STEM Teacher Interactions
Collect/analyze MAP scores (3.3)	Each Spring	NWEA,ePI,ePM
Collect/analyze SLO data for computer science teachers (3.3)	As MCs, courses offered	MC Instructors
Disseminate project results and PPDP model (all)	Beginning Fall ’21	PI, Co-PIs, Senior Personnel
Analyze/report program results (all)	Formative each Spring, then annual reporting	PI, Co-PIs, Senior Personnel
Convene advisory board	Fall ’20, Sum ’21, ’22, ’23	PI

C3. Feedback and Continuous Improvement

To ensure quality in the development and refinement of all parts of the CU-TLP Model, project staff will continually monitor progress through feedback and formative evaluation. The CU team and WestEd will capture feedback from teachers and schools as needs assessments, advanced credentials, and PPDPs are developed and implemented to ensure the project is executed with fidelity and to allow for continuous improvement. Feedback will be reviewed in monthly project meetings (more frequently early in the project) and shared with district partners and advisory board members to identify success and address challenges.

Once developed, the teacher and school needs assessments will need continuous refinement. Data collected on teacher/school effectiveness and assets will be compared with the results of the survey used for teachers and schools to self-report on their needs and assets. The PPDPs developed from the needs assessment will also be refined as classroom observation, student achievement, and teacher/school leader interview data are collected. Initially, decisions regarding the creation of the PPDPs will be human made, but as improvements are made to the algorithm, decisions will eventually be computer made. The quality of the recommendations will be determined using precision and recall metrics as well as more subjective metrics used for evaluating user-centric systems (Knijnenburg, Willemsen, Gantner, Soncu, & Newell, 2012).

Our instructional designer, April Pelt, will work with instructional faculty to ensure that PD offerings meet university, state, and accrediting body guidelines. To ensure that we are promoting the best online learning practices, we will partner with Clemson Online to certify all advanced credentials (MCs, courses, endorsements, and degree program) using Quality Matters, a nationally recognized, research-based quality assurance tool (Shattuck, 2012; Varonis, 2014). In addition to following Quality Matters' rigorous standards for online course development, we

will review course evaluations to confirm that there is continued alignment between the needs of the teachers/school and the course content. Courses that achieve proficiency on the review elements demonstrate structured quality and design elements that provide an accessible, learner-centered structure that supports effective communication, assessment, and engagement.

In year 3, project and evaluation teams will compare human vs. machine decision-making alignment of PPDP outputs. This information will be useful for improving development processes for human and recommender system algorithms.

D. QUALITY OF PROJECT EVALUATION

WestEd will conduct a formative and summative evaluation of CU-TLP. The formative evaluation will provide timely programmatic information to project leadership at Clemson to identify and build on successes and address challenges, thereby improving the likelihood that the project is implemented with fidelity and produces anticipated outcomes. Further, the data gathered during the formative evaluation will be useful for understanding efforts to develop PPDPs built on individual needs assessments, the development and implementation of the recommender system, and the alignment of advanced credentials to the participants' needs and goals in their PPDPs. The summative evaluation will rely on a combination of analytic methods, including propensity score matching (PSM) to minimize bias between treatment and control groups, and will meet WWC standards with reservations. Table 7 summarizes the evaluation questions aligned with the project's goals listed in section A.

D1. Extent to Which the Methods of Evaluation Will Produce Evidence About the Project's Effectiveness That Would Meet the WWC Standards With or Without Reservations

WestEd will focus on student achievement levels to produce evidence of effectiveness that meets WWC standards with reservations (Table 4, Objective 3.3). WestEd will rely on a quasi-experimental design (QED) that employs PSM to minimize bias between the treatment and

comparison groups by matching participating STEM teachers to STEM teachers in nonparticipating schools to meet WWC standards with reservations.[4] WestEd will first identify comparison schools through PSM using pre-scores from the SC Ready mathematics and SCPASS science assessment data, as well as urbanicity, school size, and school-level student demographics.[5] Within those matched schools, WestEd will conduct a second PSM at the teacher level, using classroom-level achievement and demographics to identify teachers for the comparison group. The quality of matches will be assessed by conducting baseline equivalence on the analytic samples and follow WWC guidelines for statistical controls should matches exceed the required threshold standards. The evaluation will follow WWC guidelines for assessing attrition, including reporting both cluster-level attrition and non-response of individuals. Risk of joiners will also be assessed and managed according to the Teacher Effectiveness Protocol. The study will be sufficiently powered at 16 districts and 35 schools, with 527 teachers in the treatment group and a comparable number of teachers in the control group. Using Optimal Design, we estimated that we can detect an effect size of greater than 0.20 at 80% power, with intra-class correlations ranging from .11 to .19.[6]

D2. Extent to Which the Methods of the Evaluation Will Provide Performance Feedback and Permit Periodic Assessment of Progress Toward Achieving Outcomes

WestEd will use a variety of methodologies to capture the project's progress toward implementation. Ongoing formative data collection is critical for ensuring project staff have relevant and timely information to make midcourse corrections. It is also important for

[4] Other designs, including randomized controlled trials (RCT) and regression discontinuity designs (RDD), were considered for this evaluation but deemed infeasible due to the method used for recruiting participants (including establishing a minimum participation rate within a school for their eligibility to participate).
[5] Due to the cancellation of assessments in 2019-2020 from COVID-19 school closures, we will use 2018-2019 data as our baseline data (also see Appendix H).
[6] We identified these ICCs for grades 6-8 mathematics achievement under a pre-test and demographic covariate model from Hedges and Hedberg (2007).

understanding how implementation impacts the project's findings and which parts of implementation are critical for sustaining the project. Below are the data collection activities which will produce ongoing formative data to help guide the project.

Surveys. Baseline surveys, which will be administered in partnership with CU's needs assessment, will ask participants information about their current district and school, motivations and goals for participating in the program, and academic/professional background. WestEd will administer annual surveys to evaluate: (1) participants' perceived usefulness of the PPDPs and credentialing pathways, (2) support provided by the program and school leaders, and (3) suggestions for improving their participant experience. Surveys will also track teachers' practices as it aligns to their PPDPs, completion of advanced credentials, and perceptions of how the program is impacting outcomes, such as student achievement.

Qualitative data collection. WestEd will conduct interviews and focus groups with CU leadership, PD facilitators, and CU researchers annually, with a focus on the development of the needs assessment, PPDPs, and advanced credentials. Interviews and focus groups with a random sample of participating teachers and leaders will also be conducted annually, with a focus on the following themes: alignment of PPDPs to emerging school and teacher needs; facilitators and barriers to completing the PPDPs; pedagogical changes; and participation in and completion of advanced credentials. The random sampling of interviews and focus groups with participants will allow for deeper learning about project implementation and provide opportunities for stakeholders to have input about changes to the program to improve participant experience.

Program data. WestEd will collect basic participant information annually from project leadership, including demographics, needs identified in the needs assessments, and enrollment/completion of advanced credentials. WestEd will also collect teacher PPDPs

annually. The PPDPs will be databased to: (1) allow descriptive analyses of focal areas and their relationships to project outcomes, (2) compare planned versus actual participation in professional development, and (3) compare human-developed and recommender-developed plans.

Formative feedback reporting: As part of a continuous improvement effort, WestEd will provide implementation briefs following each data collection cycle to ensure project staff have information to reflect and make necessary changes as well as leverage implementation drivers. In addition, formative data will be loaded into a private Tableau dashboard to provide project leadership with just-in-time information and to examine overall trends and differences in cohorts, geography, and content areas. As data collection continues, these reporting mechanisms will be important for demonstrating the extent to which the project uses findings to make improvements to the program and how implementation impacts intended outcomes.

D3. Objective Performance Measures Clearly Related to Intended Outcomes

WestEd will use a variety of methodologies and qualitative and quantitative data sources to measure and track the project's performance and outcomes. Table 7 and the narrative that follows list the project's evaluation questions by project objective and performance measure along with the data sources that the evaluation will use to track performance and outcomes.

Table 7: Project Objectives, Evaluation Questions, and Data Sources

Evaluation Questions by Objective and Performance Measure	Data Sources
Goal 1: Create a recommender system to provide guiding suggestions for human development of PPDPs.	
Objective 1.1: Assess needs of STEM teachers/schools. ***527 teachers and school districts/leaders in 16 districts will complete needs assessment to inform creation and refinement of PPDP.***	
• To what extent are principals and teachers recruited for the program overall? By opportunity zone? • To what extent do principals and teachers participate in the needs assessment? • How does CU-TLP use the needs assessment to inform the development of the participants' PPDPs? • To what extent do the participants perceive the PPDPs to be reflective of their needs?	• Program data on recruitment and participants • Respondent data from needs assessment compared to recruitment data • Interviews with PD facilitators and project leadership; documentation from needs assessment reporting • Surveys of teachers and leaders; random sampling of interviews with teachers and leaders

Objective 1.2: Develop and implement recommender system algorithm. ***527 teachers provided with PPDPs to guide advanced credential pursuits.***	
• To what extent do the PD facilitators and CU researchers work together to develop the recommender system using the needs assessment? • To what extent is the recommender system developed and implemented as intended? • To what extent do the PPDPs generated from the recommender system exhibit face validity?	• Program data on recruitment and participants • Document review (including PPDPs) • Interviews with PD facilitators, CU researchers, and project leadership
Objective 1.3: Establish growth targets for teachers. ***Growth targets for all teachers aligned to needs assessment data from teacher and school.***	
• To what extent do teachers and leaders perceive the growth targets as reasonable?	• Surveys of teachers and leaders; random sampling of interviews with teachers and leaders • Document review (including PPDPs)
Objective 1.4: Assess the effectiveness of the recommender system in establishing PPDPs for teachers. ***At least 75% of PPDPs will be followed by teachers.***	
• To what extent do the PPDPs developed under the recommender system reflect the needs of teachers and leaders? • To what extent do the teachers follow the PPDPs? • What % of teachers follow the human-developed PPDPs compared to the recommender-developed PPDPs? • Do the PPDPs generated from the recommender system match the PPDPs that are human generated? • To what extent do the PPDPs generated from the recommender system lead to more effective STEM teachers compared to the human-generated PPDPs?* • To what extent do the PPDPs generated from the recommender system improve teacher retention rates compared to human-generated PPDPs?* • To what extent do students of participants with recommender-system-generated PPDPs demonstrate higher achievement growth compared to similar students in classes taught by participants with human-generated PPDPs?*	• Surveys of teachers and leaders; random sampling of interviews with teachers and leaders • Interviews with PD facilitators, CU researchers, and project leadership • Document review (including PPDPs) • PD and course enrollment data • NWEA mathematics growth scores* • SC Ready mathematics achievement scores* • Teacher retention data*
Goal 2: Customize professional development to align with PPDPs.	
Objective 2.1: Use the PPDPs to guide advanced credential offerings. ***26 micro-credentials developed and refined; 12 courses, 3 endorsements, and 1 degree program refined.***	
• To what extent do the credential offerings align with the needs identified by teachers and leaders? • To what extent do the credential offerings align with the PPDPs? • To what extent is there a relationship between the PPDPs and credentials attained?	• Respondent data from needs assessment compared to recruitment data • Document review (including PPDPs) • MC and course syllabi • Interviews with PD facilitators and project leadership • Course completion data
Objective 2.2: Develop and implement stackable, certified, advanced credential options to support growth of STEM teachers. ***At least 90% of 26 micro-credentials, 12 courses, 3 endorsements, and 1 program certified using Quality Matters by year 3.***	

• To what extent are the credential options certified as high quality? • To what extent do the teachers and leaders perceive the course offerings as high quality? • To what extent are course offerings developed and refined to meet the needs of teachers and leaders?	• Program data on Quality Matters certification • Interviews with PD facilitators, CU researchers, and project leadership • Surveys of teachers and leaders; random sampling of interviews with teachers and leaders
Goal 3: Evaluate CU-TLP's effectiveness.	
Objective 3.1: Increase STEM teacher effectiveness. ***Significant increase in effectiveness for STEM teachers by year 2 of participation.***	
• To what extent do the PPDPs and credential offerings lead to more effective STEM teachers?	• SCTS 4.0 rubric ratings • CS SLOs • Surveys of teachers and leaders; random sampling of interviews with teachers and leaders
Objective 3.2: Improve retention of effective STEM teachers. ***Significant increase in STEM teacher retention.***	
• To what extent does project participation improve the retention of effective STEM teachers?	• Teacher retention rates
Objective 3.3: Increase student achievement in STEM classrooms. ***Higher rates of growth for students of participating teachers are higher than those for students of non-participating teachers.***	
• Do students in classrooms of CU-TLP participants demonstrate higher growth and achievement levels compared to similar students in non-participating classrooms? • To what extent are effects sustained after participation?	• NWEA mathematics growth scores • SC Ready mathematics achievement scores

*Evaluation questions to be addressed if project is extended into years 4 and 5.

Goal 1: Create a recommender system to provide guiding suggestions for human development of PPDPs.

1.1: 527 teachers and school districts/leaders in 16 districts will complete needs assessment to inform creation and refinement of PPDP. The project will use program data on recruitment and participation in the project, as well as respondent data from the needs assessment, to understand how many teachers and schools were recruited and how many completed the needs assessment.

1.2: 527 teachers provided with PPDPs to guide advanced credential pursuits. The evaluation will collect program data on participation as well as PPDP development and outputs.

1.3: Growth targets for all teachers aligned to needs assessment data from teacher and school. Our review of the PPDPs will track the extent to which growth targets are established and aligned with needs assessment. Annual surveys and interviews with participants will provide perceptions of the growth targets and reasonableness.

1.4: At least 75% of PPDPs will be followed by teachers. Program data, including PPDPs and enrollment in professional development and course offerings, will be tracked, and the percentage of human- versus recommender-developed PPDPs will be compared.

Goal 2: Customize professional development to align with PPDPs.

2.1: 26 micro-credentials developed and refined; 12 courses, 3 endorsements, and 1 degree program refined. Evaluators will collect course syllabi and credential offering descriptions. Continued document review of PPDPs and the respondent data from the needs assessment will compare the extent to which these PD offerings align with the needs of the participants.

2.2: At least 90% of 26 micro-credentials, 12 courses, 3 endorsements, and 1 program certified using Quality Matters by year 3. In year 3, we will collect program data on the certification process and will interview project leadership regarding the certification process. Qualitative data collection will supplement review to determine the extent to which participants find the courses high quality.

Goal 3: Evaluate CU-TLP's effectiveness.

3.1: Significant increase in effectiveness of STEM teachers. The project will use the SCTS 4.0 state observation rubric to measure teaching effectiveness before the participants begin their PPDPs and throughout their participation and completion of the project. WestEd, in partnership with CU, will track teacher observation ratings over time. The project will also examine the extent to which participants meet or exceed their growth targets set forth in their PPDPs.

3.2: Significant increase in retention of STEM teachers. WestEd will use STEM teacher retention rates from the 2019-20 school year to establish baseline retention rates and compare retention rates at participating schools against comparison schools, districts, and state. We will also collect 2017-2018 and 2018-2019 retention data to ensure that we contextualize any large differences in baseline data due to the COVID-19 crisis. WestEd will collect extant data on

participating and non-participating schools and districts annually to assess the impact of the CU-TLP project on within-school teacher retention. Estimation models may rely on survival analyses, accounting for teachers nested within school through multilevel models.

3.3: Significant increase in student achievement of participating teachersè classrooms. WestEd will use SCPASS science and SC Ready mathematics assessments, comparing the percentage of students in participating classrooms who achieve, meet, or exceed performance levels on SC Ready mathematics and SCPASS science with students in non-participating classrooms. We will use the first cohort of teachers to track sustained effects of the project, following those teachers through year 3 to measure student achievement after their participation in the project has ended.

We will supplement our analysis with NWEA to measure student growth scores of students in participating classrooms compared to growth scores of students in non-participating classrooms using the NWEA Virtual Comparison Groups.[7] In order to estimate outcomes associated with CU-TLP on student achievement, WestEd will rely on multilevel models, with students (level 1) nested within teachers (level 2) and teachers nested within schools (level 3), if there is significant variance in state assessment and NWEA MAP scores at the school level. The models will include matching covariates as statistical controls.

Outcomes Reporting:

At the outset, WestEd will develop a full evaluation plan and, if required, submit to the U.S. Department of Education to ensure that the plan will meet WWC standards with reservations. WestEd will provide an annual evaluation report that tracks performance and outcome data for submission with the annual report to the U.S. Department of Education. At the end of the project, WestEd will produce and release a publicly available report for review by WWC.

[7] This will also ensure that our student achievement outcomes meet WWC standards, as the NWEA Virtual Comparison Groups are proprietary, and we cannot ensure it will meet WWC standards.

References:

ACT. (2018). The condition of college & career readiness 2018: South Carolina key findings. Retrieved from http://www.act.org/content/dam/act/unsecured/documents/cccr2018/South-Carolina-CCCR-2018.pdf

Barnett, J. H., Rinthapol, N., & Hudgens, T. (2014). TAP Research Summary: Examining the Evidence and Impact of" TAP: The System for Teacher and Student Advancement". *National Institute for Excellence in Teaching*.

Belfield, C.eR., Levin, H. M., & Rosen, R. (2012). The Economic Value of Opportunity Youth. *Corporation for National and Community Service*.

Borko, H., & Livingston, C. (1989). Cognition and improvisation: Differences in mathematics instruction by expert and novice teachers. *American Educational Research Journal, 26*(4), 473-498.

Caddle, M. C., Bautista, A., Brizuela, B. M., & Sharpe, S. T. (2016). Evaluating mathematics teachers' professional development motivations and needs. *Journal of Research in Mathematics Education, 5*(2), 112-134.

Center for Educator Recruitment Retention & Advancement [CERRA]. (2019). *South Carolina Annual Educator Supply & Demand Report*. Retrieved from Rock Hill, SC: https://www.cerra.org/uploads/1/7/6/8/17684955/2017-18_supply_demand_report.pdf

Cowan, J., & Goldhaber, D. (2016). National Board certification and teacher effectiveness: evidence from Washington state. *Journal of Research on Educational Effectiveness, 9*(3), 233-258.

Darling-Hammond, L., Hyler, M. E., & Gardner, M. (2017). Effective teacher professional development. In: Palo Alto, CA: Learning Policy Institute.

Fok, A. W. P., & Ip, H. H. S. (2006). An Agent-based framework for personalized learning in continuing professional development. *International Journal of Distance Education Technologies, 4*(3), 48-61.

Hattie, J. (2012). *Visible learning for teachers: Maximizing impact on learning*: Routledge.

Haynes, M. (2014). On the Path to Equity: Improving the Effectiveness of Beginning Teachers. *Alliance for Excellent Education*.

Hedges, L. V., & Hedberg, E. C. (2007). Intraclass correlation values for palnning group-randomized trials in education. *Educational Evaluation and Policy Analysis, 29*(1), 60-87.

Institute of Education Sciences. (2017). The Nation's Report Card. Retrieved from http://nationsreportcard.gov

Isenberg, E., Max, J., Gleason, P., Johnson, M., Deutsch, J., & Hansen, M. (2016). *Do low-income students have equal access to effective teachers? Evidence from 26 districts (No. ce9ae6b49ff34e388113f31ca621bfa8)*. Mathematica Policy Research.

Knijnenburg, B. P., Sivakumar, S., & Wilkinson, D. (2016). *Recommender systems for self-actualization*.

Knijnenburg, B. P., Willemsen, M. C., Gantner, Z., Soncu, H., & Newell, C. (2012). Explaining the user experience of recommender systems. *User Modeling and User-Adapted Interaction, 22*(4-5), 441-504.

Louis, K. S., Leithwood, K., Wahlstrom, K. L., Anderson, S. E., Michlin, M., & Mascall, B. (2010). Learning from leadership: Investigating the links to improved student learning.

Center for Applied Research and Educational Improvement/University of Minnesota and Ontario Institute for Studies in Education/University of Toronto, 42, 50.

Lu, J., Wu, D., Mao, M., Wang, W., & Zhang, G. (2015). Recommender system application developments: a survey. *Decision Support Systems, 74*, 12-32.

Marshall, J.eC. (2016). *The highly effective teacher: 7 classroom-tested practices that foster student success*. Alexandria, VA: ASCD.

Marshall, J.eC., & Alston, D. M. (2014). Effective, sustained inquiry-based instruction promotes higher science proficiency among all groups: A five-year analysis. *Journal of Science Teacher Education, 25*(7), 807-821. doi:10.1007/s10972-014-9401-4

Marshall, J.eC., Smart, J.eB., & Alston, D. M. (2017). Inquiry-based instruction: A possible solution to improving student learning of both science concepts and scientific practices. *International Journal for Science and Mathematics, 15*(5), 777-796. doi:10.1007/s10763-016-9718-x

Martinez, M. (2019). PERSONALIZATION TURNS LEARNING INTO A JOURNEY. *The Learning Professional, 40*(4), 9-12.

Max, J., & Glazerman, S. (2014). *Do Disadvantaged Students Get Less Effective Teaching? Key Findings from Recent Institute of Education Sciences Studies (Evaluation Brief)*. Retrieved from

Meyers, C., Molefe, A., Dhillon, S., & Zhu, B. (2015). The Impact of eMINTS Professional Development on Teacher Instruction and Student Achievement.

National Center for Education Statistics. (2019). Number and percentage of public school students eligible for free or reduced lunch, by state. Retrieved from https://nces.ed.gov/ccd/elsi/tableGenerator.aspx?savedTableID_55260

National Science & Technology Council. (2018). Charting a Course for Success: America's Strategy for STEM Education. In: Office of Science and Technology Policy Washington, DC.

Robinson, V. M., Lloyd, C. A., & Rowe, K. J. (2008). The impact of leadership on student outcomes: An analysis of the differential effects of leadership types. *Educational administration quarterly, 44*(5), 635-674.

Schafer, J. B., Frankowski, D., Herlocker, J., & Sen, S. (2007). Collaborative filtering recommender systems. In *The adaptive web* (pp. 291-324): Springer.

Shattuck, K. (2012). What we're learning from Quality Matters-focused research: Research, practice, continuous improvement. *Quality Matters*, 1-29.

South Carolina Department of Education. (2020a). South Carolina District and School Report Cards. Retrieved from https://screportcards.ed.sc.gov/

South Carolina Department of Education. (2020b). South Carolina Teaching Standards 4.0. Retrieved from https://ed.sc.gov/educators/educator-effectiveness/south-carolina-teaching-standards-4-0/

Supovitz, J. A., & Turner, H. (2000). The effects of professional development on science teaching practices and classroom culture. *Journal of Research in Science Teaching, 37*(9), 963-980. doi:10.1002/1098-2736(200011)37:9<963::Aid-Tea6>3.0.Co;2-0

Tomlinson, C. A. (2014). *The differentiated classroom: Responding to the needs of all learners* (2nd ed.). Alexandria, VA: ASCD.

Trotter, Y. D. (2006). Adult Learning Theories: Impacting Professional Development Programs. *Delta Kappa Gamma Bulletin, 72*(2).

U.S. News and World Report. (2020). Best Online Master's in Education Programs. Retrieved from https://www.usnews.com/education/online-education/education/rankings

Varonis, E. M. (2014). Most courses are not born digital: An overview of the Quality Matters peer review process for online course design. *Campus-Wide Information Systems, 31*(4), 217-229.

Wells, M. (2014). Elements of effective and sustainable professional learning. *Professional development in education, 40*(3), 488-504.