An Evaluation of the Literacy-Infused Science Using Technology Innovation Opportunity (LISTO)
i3 Evaluation (Valid 45)
Addendum Report

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About the Center for Research and Reform in Education (CRRE) at the Johns Hopkins University School of Education

The Center for Research and Reform in Education (CRRE) is a research center within the Johns Hopkins University School of Education. Established in 2004, our major goal is to improve the quality of education for children in grades pre-K to 12 through high-quality research and the dissemination of evidence-based research. CRRE is committed to expanding the body of evidence on the effectiveness of educational programs and initiatives and assisting organizations and school districts to obtain the information they need to make evidence-based decisions.

Specializing in independent program evaluations, CRRE's research department evaluates the impacts of programs and services through four levels of evaluation studies: (1) design and implementation quality; (2) development; (3) efficacy; and (4) effectiveness. In terms of content areas, CRRE specializes in evaluations of educational technology and technology integration; social-emotional learning; professional development; school reform; programs for English learners; and multiple core subject curriculum areas. CRRE staff work with educators and program developers to design studies that are consistent with their organization's objectives and that meet the specific needs of clients. We evaluate programs locally, nationally, and internationally.

CRRE researchers include numerous Johns Hopkins University professors and research staff with backgrounds including quantitative, qualitative, and evaluative research. The research team has published over 200 research documents, and within the past five years alone, CRRE has conducted over 45 program evaluations nearing $10 million.

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EXECUTIVE SUMMARY:
An Evaluation of the Literacy-Infused Science Using Technology Innovation Opportunity (LISTO) Validation Project

Overview

This study is an evaluation of the Literacy-Infused Science Using Technology Innovation Opportunity (LISTO) validation project (Valid 45). The LISTO project was funded by the Investing in Innovation (i3) Fund.[1] It involved a multi-year intervention that provided virtual professional development and coaching, and literacy-infused science curricula to fifth-grade science teachers who taught predominantly low-income students and in predominantly rural public schools in Texas.

Multiple professors at Texas A&M University were the recipients of the i3 grant that funded LISTO. The Center for Research and Reform in Education (CRRE) at Johns Hopkins University School of Education was the independent, third-party evaluator of LISTO. This report describes the method and findings of the evaluation.

Program Description

The purpose of Project LISTO is to support the instructional capacity of science educators and to validate innovative practices and strategies via previously developed interventions that address literacy-infused science and technology integration with standards-aligned curriculum. Specifically, LISTO compared enhanced Literacy-Infused Science (LIS) instruction to that of typical science instruction. Project LISTO provided standards-aligned, literacy-infused science curricula, ongoing virtual professional development, and ongoing virtual mentoring and coaching to fifth-grade science teachers.

It is important to note that there were major barriers to this program implementation. In 2017, Hurricane Harvey brought many changes that impacted the first year of implementation for Project LISTO, including the launching of the first year of the project, implementation of all components, and fidelity of implementation. This extreme weather event included eight days of heavy rainfall from August 25–September 1, resulting in more than 60 inches of rain that caused catastrophic flooding. School districts across Texas were hard hit, with over 1.4 million students directly impacted by the storm, more than $970 million worth of school building damage, and an estimated $1 billion school funding gap (Morath, 2017). Even after a full year, with the state's recovery still "far from over," according to the *Texas Tribune* survey, 8% of people had not yet returned to their homes (Formby, 2018). The hurricane caused a long-term impact on schools, teachers, students, and their families in the affected areas. Furthermore, the COVID-19 pandemic resulted in school closures, which affected outcome measures in Year 3, specifically. Together, these impacts included students missing instructional hours before and after schools reopened, staff periodically being absent from work or unable to return to their classrooms fully, and

[1] The award number is U411B160011.

schools under high pressure of gathering resources and funding for students and staff, which drove down students' tests scores (Davis et al., 2021).

Seven LISTO school districts (20%) are located within the declared disaster counties, inclusive of districts who applied for related Texas Education Agency accommodations that were directly impacted. Within these districts, a total of 14 LISTO campuses (17%) and 28 teachers (23%) were adversely affected by flooding and damage caused in the wake of Hurricane Harvey. A higher percentage of teachers were impacted as compared to control (29.8% treatment; 17.1% control). Teachers, students, and their families in coastal areas were displaced and some educational facilities were shuttered while others were relocated to different parts of the community and state. One treatment campus in the city of Houston, Texas in Houston ISD was damaged to the point that the building was demolished and rebuilt over the next two years. The staff and students were temporarily moved to an alternate location, which took weeks to prepare. Students missed more than four weeks of classes and started back on September 25, 2017. These impacts included delaying the beginning of year testing, curriculum implementation, and professional development schedules for the original confirmatory group. Additionally, the observations were incomplete for the baseline collection. Two component parts of the intervention were delayed as well. The Science Role Models and Mentors did not engage until the second semester, and the Family Involvement in Science did not begin until Year 2.

Literacy-Infused Science Using Technology Innovation Opportunities (LISTO) Curricula. Teachers received LISTO curricular materials, which included 25 weeks of standards-aligned lesson plans, lesson scripts, related resources, and hands-on science activity supplies. Lessons were designed to be implemented within an 80-minute science block. Detailed, scripted lessons were organized using the 5E instructional model (in which at least three of the five E's—engage, explore, explain, elaborate, evaluate—were implemented in each lesson) and included embedded literacy-skills to facilitate listening, speaking, reading, and writing. Some of the strategies included engaging questioning; partner and group work; direct instruction of science academic vocabulary using visuals and student friendly definitions; supporting reading through pre-teaching pronunciation of vocabulary and words that are challenging to decode; strategic partner reading; leveled questioning; highlighting expository text features; sentence stems; graphic organizers; and integration of student use of technology via tablets.

LISTO included two sub-components: Family Involvement in Science (FIS) and Scientists as Role Models and Mentors (SRM^2). Although the intent was to implement both of these components starting in Year 1, they were not implemented until Year 2. Therefore, there was no influence or impact from these subcomponents on this confirmatory analysis. Family Involvement in Science (FIS) consisted of take-home booklets that included activities to engage family members in science, including vocabulary development, reading selection related to the science concept, family science activities, and science literature resources. During the spring semester of Year 2, FIS kits inclusive of FIS booklets and GoVision goggles were sent to treatment teachers to send home with consented students. During Year 2, the SRM^2 virtual mentoring component featured contributions from eight university science mentors who were strategically recruited so that their area of science field, interest, and science experiences directly aligned with LIS curriculum units. Videos of the scientists were embedded into the introductory scenarios (setting a real-life context for learning the science content), and also embedded into the closing unit activity, a science challenge that brought together the skills and content addressed in the unit. During Year 2, 19 teachers participated in SRM[2], yielding 951 student questions for scientists. The questions were synthesized, and the scientists generated responses in return. Importantly, however, this comprehensive intervention was not completely implemented fully throughout the first year.

Virtual Professional Development (VPD). The VPD sessions were conducted using GoToTraining, an interactive virtual platform that allows screen sharing, webcam sharing, voice chat, type chat, and breakout sessions. The VPD sessions included professional growth opportunities to develop teachers' knowledge of science content and literacy-integration, including strategies that support listening, speaking, reading and writing in science—such as vocabulary instruction, reading comprehension, oral language development, and writing in science. VPD sessions also included a preview of upcoming curriculum units, demonstrations and modeling videos, project updates, teacher feedback, and teacher spotlights. During Year 1, initial onboarding VPD sessions were scheduled weekly during September 2017. However, Hurricane Harvey adversely impacted 17 of the treatment teachers (29.8%) in six school districts. From October through the beginning of April, treatment teachers attended 90 minutes of virtual training every two weeks focused on implementation of LISTO curriculum and literacy-infused instructional strategies. On average, a total of three hours per month were reported. VPD sessions mid-April through May were related to teacher feedback, surveys, and focus group interviews. During Year 2, treatment teachers received approximately 60 minutes of virtual training every two weeks from September to April, totaling two hours per month, on average. There were nine VPD sessions offered in Year 3 and four sessions offered in Year 4, which saw varying degrees of participation.

Virtual Mentoring and Coaching (VMC). As part of the technology innovations, participating fifth grade teachers received the Applied Pedagogical Education Xtra Imaging System (APEXIS) hardware and access to the Hoot Education platform, through which VMC was conducted. Teachers participated in virtual coaching sessions in which coaches provided real-time feedback to teachers as they implemented the LISTO curriculum. Due to delays caused by Hurricane Harvey, additional time was necessary to get observation equipment in place and to provide training and ongoing supports for teachers to utilize the online platform and classroom technology. As a result, VMC was delayed until spring 2018, and monitoring fidelity of teacher implementation of the LISTO lessons did not occur during the first semester of the project. During the second semester, coaches conducted two live, real-time coaching sessions and provided written feedback to identify what went well during the lesson and areas of improvement related to lesson plan and instructional strategy implementation. Teachers were asked to reflect on the feedback. Coaches met to discuss trends observed during VMC sessions and strategically incorporated supports within the ongoing VPD sessions. During Year 2, teachers participated in five VMC sessions including an initial goal-setting session and four real-time coaching sessions. In addition to written feedback, teachers also participated in a virtual reflection session each semester in which the teacher and coach met synchronously online to review selected time stamps of a recorded classroom observation and reflect on teacher LISTO lesson implementation and teacher-selected instructional goals. In addition to two reflection sessions, teachers participated in four VMC sessions in Year 3 and two sessions in Year 4.

Research Design

The evaluation of LISTO involved a multisite cluster randomized trial (CRT) designed to meet the Every Student Succeeds Act (ESSA) Tier 2 standards for “moderate” evidence, as well as the What Works Clearinghouse (WWC) standards "with reservations." The study estimated program impacts on both student and teacher outcomes and documented the fidelity of implementation and educators’ perceptions of program quality.

Schools with participating fifth grade science teachers were randomly assigned to either the treatment or control condition. Schools were randomly assigned within district blocks when more than one school in a district chose to participate in the study. Fifth grade science teachers may have participated in the intervention for either one or two years over the 2017–18 and 2018–19 school years, and some teachers were allowed to join the study after the random assignment of schools. Students were exposed to the intervention only in their fifth-grade year, either in the 2017–18 or 2018–19 school year. Again, data for the year 2017–18 reflected a low fidelity of implementation for the entire first semester, due to the reasons previously discussed. The resulting impacts included delaying the beginning of year testing, curriculum implementation, baseline observations, and professional development schedules for the original confirmatory group.

Research Questions

1. What is the impact of LISTO on fifth grade students’ science and reading achievement after one year of treatment compared with the business-as-usual condition?
2. What is the impact of LISTO on fifth grade science teachers' instructional delivery after one or two years of treatment compared with the business-as-usual condition?
3. Was each key component of LISTO implemented with fidelity?
4. How do teachers perceive the effectiveness of the VPD, and do they perceive their practice to improve with reflections included in training?
5. How do teachers and coaches perceive the ease of use and quality of VMC using Hoot Education and APEXIS software and hardware?

Sample

Prior to the 2017–18 school year, LISTO Texas A&M personnel recruited 71 Texas schools in 37 school districts in which low-income students comprised more than 50% of the student population. Schools were randomized to either the treatment or control condition within district, whenever possible. Fifth grade science teachers in participating schools were then recruited to participate in the study. For each school, up to four classes or rotations were selected to participate in the study. Students were included in the study if they were in the sampled classes, and if their parents provided consent for them to participate. Students were exposed to the program in their fifth-grade year only. There were 5,180 students in Years 1-2 and an additional 932 students added in Year 4. Although 2,361 students were served in Year 3, no outcome data was available due to the COVID-19 pandemic, which interrupted testing. The sample numbers do vary, depending on data availability for each outcome (see i3 Tables in Appendix A).

One hundred twenty-one teachers participated in the study for 2017–18, and teachers were allowed to join the study through the beginning of the following school year. This count reflects teachers who had non-missing student outcomes in either of the 2017–18 or 2018–19 school years or had at least one observation submitted in the 2018–19 school year. In Years 3 and 4, some teacher attrition did occur; there were 61 and 41 teacher participants, respectively.

Measures and Instruments

The evaluation examined the impact of LISTO on the following student outcomes:

- State of Texas Assessments of Academic Readiness (STAAR) Science
- STAAR Reading
- Iowa Test of Basic Skills (ITBS) Science
- Big Ideas in Science Assessment (BISA)
- Science Interest Survey

Program impacts were also estimated for researcher-made teacher outcomes including:

- Focus on academic tasks and/or student feedback while presenting new science content
- Focus on oral language while presenting new science content
- Use of research-based instructional practices while teaching science

Fidelity of program-level implementation was measured by attendance of virtual professional development and coaching sessions, and by receipt of the program's curricular materials. Perceived program quality was captured by teacher responses collected via surveys and in focus groups and interviews.

Analytic Approach

The impact of LISTO on student and teacher outcomes was estimated using hierarchical linear modeling. Propensity score weighting was also used to estimate program impacts on teacher outcomes due to large differences on the pretest measure because pretest data were collected after program implementation had begun.

Findings

Outcomes collected in the 2017–18 school year were considered to be exploratory, given the timing of Hurricane Harvey, which hit Texas in August of 2017, as mentioned earlier. Outcomes in the 2018–19 school year served as the confirmatory contrasts. In both school years, students were exposed to the program through their teachers in only their fifth-grade year. One year of exposure for students may have been insufficient to increase student achievement in science or reading, yet some impacts were observed. And, due to the COVID-19 pandemic, in Year 3, only BISA, ITBS science, and science interest survey scores were collected and only in the fall of the 2019–20 school year. STAAR Science and Reading scores were not collected during Year 3 (2019–20). Thus, the only contrasts we were able to conduct on student achievement were those focusing on Year 4 administrations of STAAR Science and Reading, BISA, ITBS Science, and the science interest survey.

Program impacts. The following program impacts should be cautiously interpreted due to limitations of delayed and incomplete implementation in the first year of the project as previously described. LISTO resulted in increased teacher capacity to implement research-based strategies while teaching science content, yet this improvement did not necessarily translate into improved student achievement in science or reading. The LISTO professional development and coaching covered pedagogical strategies for teaching science, including those that have been shown to improve literacy and be particularly effective for English learners. Findings showed that LISTO teachers implemented these research-based pedagogical strategies to a greater extent than did control teachers. The research team believes that due to the impacts of Hurricane Harvey and issues with teachers submitting the first round of classroom observation recordings, there was a low return on the first round of classroom observations during Year 1.

Results were mixed across years. In 2017–18, after the first year of program implementation, there was a statistically significant difference in science achievement for students in LISTO versus control classrooms. LISTO students scored approximately 48 points lower than did control students on the STAAR Science assessment. Students in LISTO classrooms expressed slightly lower average interest in science than students in control classrooms by 0.07 points on a 5-point survey scale, or -0.14 standard deviations ($p < .05$).

In 2018–19, or after the second year of program implementation, students in LISTO classrooms had lower average science achievement on the state test than did students in control classrooms, but there were no statistically significant differences in student performance on formative science assessments. LISTO students underperformed control students on the STAAR Science assessment in 2018–19 by roughly 73 points or -0.13 standard deviations ($p < .05$). There were also no differences in science interest between LISTO and control students in 2018–19. However, qualitative data collected from teachers suggested that students had improved their science vocabulary as a result of LISTO participation, which led to improvements in student engagement and self-efficacy. Student interaction and engagement are higher when students interpret the activities and content to be relevant and challenging (Nguyen et al., 2018; Davis & McPartland, 2012).

In 2020–21, fifth grade students in LISTO classrooms did not outperform similar, control peers on formative science assessments (e.g., ITBS Science, BISA), though it should be noted that there were considerably fewer schools (and students) that provided achievement data for Year 4 analyses, compared to previous years. Furthermore, results generally showed null or negative program effects in science achievement and interest. LISTO students had slightly lower average interest in science (determined by a student survey) than control students in 2020–21 by 0.10 points on a 5-point survey scale, or -0.14 standard deviations. There were no significant differences between groups on the three measures of science achievement in 2020–21, as measured by the STAAR Science, ITBS Science, and BISA assessments. Compared to control students, LISTO students scored slightly higher on the STAAR Science assessment of science achievement (52.74 points, or 0.11 standard deviations) and the BISA assessment (0.11 points, or 0.02 standard deviations), but these differences were not statistically significant ($p < .05$).

There were no statistical differences in reading achievement for LISTO and control students in any study year. In 2020–21, there was no statistically significant difference between LISTO and control students. Directionally, LISTO students had lower average scores on STAAR Reading than control students, controlling for student characteristics, but these differences were not statistically significant ($p < .05$).

However, treatment teachers indicated a marked improvement in student writing, particularly with regard to scientific vocabulary. LISTO teachers reported that their students began to articulate naturally occurring, everyday scientific processes (such as rain and the water cycle) while using the correct scientific terminology. Teachers attributed this shift directly to the expository readings in the LISTO curriculum.

In both 2019–20 and 2020–21 (Years 3-4) LISTO teachers showed significantly greater gains on the Science Teacher Observation Record (STOR), relative to teachers in control schools. However, there were no significant differences between treatment and control teachers' focus on academic tasks, student feedback, or oral language when presenting new science content.

Fidelity of program implementation. Fidelity of program-level implementation was measured using teacher attendance for VPD and VMC sessions, as well as evidence that curricula materials were mailed to teachers. The fidelity of implementation for each program component was analyzed separately for each of the four study years. Teachers were excluded from the fidelity sample if (a) they did not attend any of the VPD training sessions, (b) they (or their schools) withdrew from the study, or (c) they left their schools. In all four study years, implementation of LISTO failed to meet the criterion for high fidelity as determined by participation in the VPD and VMC sessions at the teacher and school levels. The 90% attendance rate equates to an extremely high threshold for attending the VPD and VMC sessions that were offered. Because not all LISTO teachers attended the VMC and VPD sessions with the regularity that was required for a high level of fidelity, this could have contributed to a lack of positive effects on student and teacher outcomes. Receipt of curricula materials, on the other hand, did meet its intended level of fidelity, as 100% of schools with participating LISTO teachers received the materials.

Perceived program quality. Perceived quality of the program was captured by teacher surveys and focus groups, which gathered teacher perceptions about the VPD, VMC, and curricula components. Teacher perceptions of the program were overwhelmingly positive. Responses collected from surveys and focus groups indicated that the VPD and VMC sessions were extremely useful and beneficial for teachers of all backgrounds and years of experience. First-year teachers particularly appreciated the LISTO-provided curricula because it provided a clear structure and pacing guide for the class. Although some teachers reported issues with the pacing and technology, participants agreed that the trainings were of high quality.

With regard to observed program effects on students, LISTO teachers reported an increase in student engagement and confidence in science-based content. Anecdotally, teachers felt that LISTO made a noticeable impact on struggling readers. The integration of technology and the literacy-infused instructional strategies fostered a more inclusive and participatory learning environment where learners interacted more with the teacher and with one another than they previously had, which empowered students in their own learning. Although the quantitative data did not show improvements on student outcomes, teachers endorsed LISTO for its ancillary benefits.

Conclusion

As previously mentioned, the first and third years of implementation encountered several delays and setbacks in full implementation for the original confirmatory group. LISTO (Valid 45), and the corresponding VPD, VMC, and curricula resources did not lead to improved student achievement in science or reading for students consented to participate in the study. There was a negative impact on students' science achievement in each of the study years, except for Year 3, when science achievement data was not collected. These quantitative findings conflicted with qualitative data collected from LISTO teachers, who indicated that the program led to improvements in both science vocabulary and engagement and self-efficacy in science for students. LISTO teachers also indicated that the program had benefited their struggling readers, but there was no observed program impact on student reading achievement in any study year. While LISTO may have yielded some benefits for students, these benefits were not well captured on the standardized tests or survey instruments employed.

LISTO had positive effects on teacher practices for a subsample of teachers, specifically on increased delivery of research-based instruction to teach science content as rated on a rubric by external reviewers. There were no differences in two other teacher outcomes, however, focused on the share of instructional time spent teaching new science content while performing various activities.

One potential reason for the lack of observed positive effects on student outcomes was that teacher participation in the VPD and VMC components of the program were not programmatically implemented with fidelity. Perhaps this was due to the unusually high threshold measurement for fidelity (90% or more). For instance, there were four VMC sessions offered in Year 3 and four VPD sessions offered in Year 4, which meant that if a teacher missed one session (an attendance rate of 75%), this would not be considered as having met fidelity. Across all four years, teachers attended 90% of the VPD sessions in 25-72% of schools and 90% of the VMC sessions in 70-88% of schools, depending on the implementation year. The participation in VMC was slightly more pronounced compared to the VPD session offerings. Due to these wide-ranging fidelity scores, it may be important to note that LISTO teachers may not have participated in the program to the extent needed to observe program impacts on student and teacher outcomes.

The LISTO teachers who participated in the program reported that the VPD and VMC were well-received by teachers. At times, teachers found the VPD and VMC sessions lengthy, yet the VPD allowed for greater teacher collaboration, and overall, teachers found the VPD and

VMC sessions to be very helpful and useful. The curricula were also appreciated by the teachers, with first-year teachers in particular benefitting from the pacing guides. Teachers also reported some barriers to implementation, including technological issues with the hardware and software and inadequate instructional time to fully engage in the implementation of the program.

In sum, LISTO appeared to improve instructional practices for a sample of teachers who implemented the program for two years with complete data (including the first round of classroom observation recordings that were missing among other teachers who participated for two years) but did not positively impact student or teacher outcomes more broadly. One likely reason for the lackluster effects was the relatively low levels of teacher participation in all VPD and VMC sessions that were offered, exacerbated by the disruption from the impacts of Hurricane Harvey, causing late starts in many districts during the first year, and the COVID-19 pandemic, which prevented outcome measures in Year 3. Arguably, having limited years (and here, less total program time than originally planned) to learn and implement a new curriculum reduces the capacity of teachers to perfect instructional strategies and consequently impact student achievement relative to control-group colleagues, who may employ less innovative but more familiar curricula. Likewise, the research team believes that only one year's exposure by students to novel ways of learning science in fifth grade without intervention in earlier grades to build their science foundation could limit the development of positive attitudes or translate to increases in learning quality from LISTO to higher achievement on standardized science and reading assessments.

Encouragingly, treatment teachers' overall positive reactions to the program suggest its potential to improve student affect and learning, but more extensive implementation experience by teachers and multi-year exposure by students starting in earlier grades may be needed to yield measurable benefits. Clearly, such focuses emerge as a highly recommended topic for future research. Again, we remind the reader that these conclusions should be interpreted with caution given the challenges presented by Hurricane Harvey and the COVID-19 pandemic described earlier in this document.

An Evaluation of the Literacy-Infused Science Using Technology Innovation Opportunity (LISTO) Validation Project

This study is an evaluation of the Literacy-Infused Science Using Technology Innovation Opportunity (LISTO) validation project (Valid 45). The LISTO project was funded by the Investing in Innovation (i3) Fund.[2] It involved a multi-year intervention that provided virtual professional development and coaching, and literacy-infused science curricula to fifth grade science teachers who taught predominantly low-income students and in predominantly rural public schools in Texas.

Multiple professors at Texas A&M University were the recipients of the i3 grant that funded LISTO. The Center for Research and Reform in Education (CRRE) at Johns Hopkins University School of Education was the independent, third-party evaluator of LISTO. This report describes the method and findings of the evaluation.

Background

Rural school districts comprise more than 50% of all school districts in Texas.[3] In fact, Texas has more schools in rural areas (over 2,000 in SY 2013–14[4]) than any other state. Rural school districts face unique challenges, including in the recruitment and retention of highly qualified teachers (Webb, 2006). Recruitment and retention of teachers in science, technology, engineering, and mathematics (STEM) subjects may be particularly difficult (Pickrom, 2015; Monk, 2007). As a result, students in rural school districts may be less likely to receive high-quality instruction in content-areas such as science and mathematics. Rural schools face additional challenges related to professional development of current teachers, due to geographic location and limited resources (Beesley, 2011; Friedrichsen et al., 2007; Glover et al., 2016; Monk, 2007).

Scientific literacy is particularly difficult for students regardless of school location (Gee, 2005), but there is evidence that low-income students, English learners (EL), and non-White/non-Asian students face particular challenges in science; just 40% of low-income students and 35% of ELs met grade-level expectations on the 2018 State of Texas Assessments of Academic Readiness (STAAR), compared with 51% of all students in Texas.[5] Additionally, low-income students and ELs were among the lowest-achieving subgroups on Texas reading assessments. In reading, 36% of low-income students and 32% of ELs met grade-level expectations on the 2018 STAAR, compared with 46% of all students in Texas. And these populations are becoming increasingly prevalent throughout Texas.

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[2] The award number is U411B160011.

[3] https://tea.texas.gov/sites/default/files/Texas_Rural_Schools_Spotlight_Report_2016-17%201.pdf

[4] https://nces.ed.gov/surveys/ruraled/tables/a.1.a.-2.asp

[5] https://rptsvr1.tea.texas.gov/cgi/sas/broker?_service=marykay&year4=2018&year2=18&_debug=0&single=N&batch=N&app=PUBLIC&title=2018+Texas+Academic+Performance+Reports&_program=perfrept.perfmast.sas&ptype=H&level=state&search=campname&namenum=&prgopt=2018%2Ftapr%2Fpaper_tapr.sas

Over the past decade, the percentages of low-income and English Learner (EL) students in Texas schools have grown steadily. The percent of low-income students increased from 56.5% of all students in 2008–09 to 60.6% of all students in 2018–19. In 2018–19, ELs accounted for approximately 19% of the K–12 student population in Texas, a 32% increase from the 2008–09 school year. Many students who are ELs are also from low-income households, which can lead to academic vulnerability.

In addition to the population growth of low-income and EL students, schools often face difficulty in the recruitment and retention of skilled teachers in rural districts. These challenges suggest teachers in rural schools may be particularly in need of additional training and resources related to teaching science, technology, engineering, and mathematics (STEM) subjects in meeting the specific academic needs of EL students and students from low-income households (Samson & Collins, 2012). By some estimates, only 30% of teachers of EL students have had the necessary training to provide effective teaching (Ballantyne, Sanderman, & Levy, 2008). A particular concern is the ability of teachers to teach subject-specific content and English language acquisition simultaneously (Correll, 2016; Lee et al., 2004; Tong et al., 2017b).

Teachers of low-income students also may need additional training in teaching subject-specific content. Students from low-income households experience an achievement gap relative to their middle- and high-income peers (Reardon, 2011; 2013), in part because they are disproportionately taught by inexperienced, out-of-field, or uncertified teachers (Peske & Haycock, 2006). Inexperienced and uncertified teachers may have less content-specific skills and knowledge than seasoned teachers who are certified in a specific content area. Teachers' content-area knowledge and their own mastery of content-specific concepts and skills impacts student achievement in the subject area (Heller et al., 2012; Lange et al., 2012).

Taking the above information into account, it is likely that additional teacher professional development and support mechanisms are needed to help teachers meet the learning needs of their EL and low-income students (Buxton & Allexsaht-Snider, 2016; Tong et al., 2017b). Considering the challenge of recruitment and retention in rural school districts, teachers in rural school districts may particularly benefit from virtual professional development and coaching programs related to content area instruction.

Professional development can increase teacher effectiveness and positively impact student achievement when it is (a) sustained over time, (b) linked with curricula, and (c) focused on both pedagogy and academic content (Darling-Hammond & Richardson, 2009; Yoon et al., 2007). Based on prior research on teacher practices and student achievement of EL students, professional development that targets cognitive-academic language proficiency within an academic content area may be particularly appropriate (Irby et al., 2010; Lara-Alecio et al., 2009; Tong, Irby, Lara-Alecio, & Mathes, 2008; Tong, Lara-Alecio, et al., 2008; Tong et al., 2017b). Tarr et al. (2008) assert that consistency between curriculum and instruction is also important in improving outcomes for all students.

In addition to targeted professional development and instructional fidelity, coaching and mentoring also positively impact academic outcomes, teacher-student interactions, and the overall educational climate for EL students (Casteel & Ballantyne, 2010; Delaney, 2012; Pruitt

& Wallace, 2012). Coaching and mentoring may positively impact student achievement, particularly for low-income students, and especially for long-term outcomes (Hagler, 2018; Hurd et al., 2012; Miranda-Chan et al., 2016). Effective teacher mentoring and coaching provide teachers with content and pedagogical expertise, modeling of instructional strategies, and feedback on teacher practice (Pruitt & Wallace, 2012).

The LISTO project builds on evidence-based best strategies for effective professional development and coaching to help teachers improve their content area instruction. LISTO is a validation study of a previous project—Project Middle School Science (MSSELL)—developed by researchers at Texas A&M University (Tong et al., 2014; Lara-Alecio et al., 2012). Project MSSELL was a literacy-infused science instructional and curricular innovation for fifth- and sixth-grade students that was funded by the National Science Foundation. Researchers at Texas A&M evaluated effects of the MSSELL program and found promising evidence of program efficacy in increasing MSSELL program but is implemented in contexts that allow researchers to validate previous findings in new school contexts, including in rural and low-income schools.

Project Description

The purpose of Project LISTO was to improve the instructional capacity of science educators and to validate innovative practices and strategies that integrated literacy-infused science instruction, technology, and standards-based curriculum. LISTO provided educators with standards-aligned, literacy-infused science curricula, ongoing virtual professional development, and ongoing virtual mentoring and coaching to fifth grade science teachers. As mentioned in the Executive Summary, multiple years of the project suffered delays and incomplete implementation, primarily due to impacts from Hurricane Harvey and COVID-19 on participating school districts and teachers.

Literacy-Infused Science Using Technology Innovation Opportunities (LISTO) Curricula. Participating treatment teachers received LISTO curricular materials, which included 25 weeks of standards-aligned lesson plans, lesson scripts, related resources, and hands-on science activity supplies. Lessons were designed to be implemented within an 80-minute science block. Detailed, scripted lessons were organized using the 5E instructional model (in which at least three of the five E's— engage, explore, explain, elaborate, evaluate—were implemented in each lesson) and included embedded literacy skills to facilitate listening, speaking, reading, and writing. Some of the strategies included working in student groups; direct teaching of science academic vocabulary using visuals and student-friendly definitions; supporting reading through pre-teaching pronunciation of vocabulary and words that are challenging to decode; strategically partnering students for reading; leveled questioning; highlighting expository text features; sentence stems; graphic organizers; and integrating student use of technology via tablets.

LISTO included two sub-components: Family Involvement in Science (FIS) and Scientists as Role Models and Mentors (SRM[2]). Although the intent was to implement both of these components starting in Year 1, they were not implemented until Year 2. Therefore, there was no influence or impact from these subcomponents on this confirmatory analysis. Family Involvement in Science (FIS) consisted of take-home booklets that included activities to engage family members in science, including vocabulary development, reading selection related to the science concept, family science activities, and science literature resources. During the spring semester of Year 2, FIS kits inclusive of FIS booklets and GoVision goggles were sent to treatment teachers to send home with consented students. The intent of the SRM^2 component was to have university scientists meet via live, synchronous, online sessions with students; however, during the second year of the project, the interaction was limited to pre-recorded video clips embedded into lesson presentations and opportunities for students to pose questions and scientists to respond. During Year 2, the SRM^2 virtual mentoring component utilized contributions from eight university science mentors who were strategically recruited so that their area of science field, interest, and science study, and whose experiences, directly aligned with LIS curriculum units. Videos of the scientists were embedded in the introductory scenarios (setting a real-life context for learning the science content) and also when students encountered the science challenge (a closing unit activity that brings together the skills and content learned in the unit). During Year 2, 19 teachers participated in SRM^2, yielding 951 student questions for scientists. The questions were synthesized and the scientists generated responses.

Virtual Professional Development (VPD). The VPD sessions were conducted using GoToTraining, an interactive virtual platform that allows screen sharing, webcam sharing, voice chat, type chat, and breakout sessions. The VPD sessions included professional growth opportunities to develop teachers' knowledge of science content and literacy-integration, including strategies that support listening, speaking, reading, and writing in science—such as vocabulary instruction, reading comprehension, oral language development, and writing in science. VPD sessions also included a preview of upcoming curriculum units, demonstrations and modeling videos, project updates, teacher feedback, and teacher spotlights. During Year 1, initial onboarding VPD sessions were scheduled weekly during September 2017. However, Hurricane Harvey adversely impacted 17 of the treatment teachers (29.8%) in six school districts. From October through the beginning of April, treatment teachers attended 90 minutes of virtual training every two weeks focused on implementation of LISTO curriculum and embedded instructional strategies. VPD sessions conducted mid-April through May were related to teacher feedback, surveys, and focus group interviews. During Year 2, treatment teachers received 60 minutes of virtual training every two weeks from September to April, on average totaling two hours per month. In Years 3-4, teachers followed a similar model for professional development; nine sessions were offered in Year 3 and four sessions were offered in Year 4.

Virtual Mentoring and Coaching (VMC). As part of the technology innovations, participating fifth grade teachers received the Applied Pedagogical Education Xtra Imaging System (APEXIS) hardware and access to the Hoot Education platform, through which VMC was conducted. Teachers participated in virtual coaching sessions in which coaches provided real-time feedback to teachers as they implemented the LIS curriculum. Due to delays caused by Hurricane Harvey, it took additional time to get observation equipment in place and to provide training and ongoing supports for teachers to utilize the online platform and classroom technology, delaying VMC implementation until spring 2018. Therefore, monitoring fidelity of teacher implementation of the LISTO lessons did not occur during the first semester of the project, and teachers were not given feedback during the first semester on their LISTO lesson implementation. During the second semester, coaches conducted two live, real-time coaching sessions and provided written feedback to identify what went well during the lesson and areas of improvement related to lesson planning and instructional strategy implementation. Teachers were asked to reflect on the feedback. Coaches met to discuss trends observed during VMC sessions, and strategically incorporated supports within the ongoing VPD sessions. During Year 2, teachers participated in five VMC sessions including an initial goal setting session and four real-time coaching sessions. In addition to written feedback, teachers also participated in a virtual reflection session each semester in which the teacher and coach met synchronously online to review selected time stamps of a recorded classroom observation and reflect on teacher LISTO lesson implementation and teacher-selected instructional goals. In addition to two reflection sessions, teachers participated in four VMC sessions in Year 3 and two sessions in Year 4.

Evaluation Design

The evaluation of LISTO involved a multisite cluster randomized trial (CRT) designed to meet the Every Student Succeeds Act (ESSA) Tier 2 standards for “moderate” evidence, as well as the What Works Clearinghouse (WWC) standards "with reservations." The study estimated program impacts on both student and teacher outcomes and documented the fidelity of implementation and educators’ perceptions of program quality.

Schools with participating fifth grade science teachers were randomly assigned to either the treatment or control condition, whenever possible. Schools were randomly assigned within district blocks, when more than one school in a district chose to participate in the study. Fifth grade science teachers may have participated in the intervention for either one or two years over the 2017–18 and 2018–19 school years, and some teachers were allowed to join the study after the random assignment of schools. Students were exposed to the intervention only in their fifth-grade year.

LISTO is expected to produce positive outcomes for students and teachers after four years of professional development supports. The confirmatory contrasts for student outcomes estimated the impact of LISTO on student achievement in science and reading (as measured by the state-mandated STAAR assessments) after one year of treatment for students, in the second year of the study (2018–19), and again in Year 4 (2020-21). The confirmatory contrasts for teacher outcomes estimated the impact of LISTO in the second year of the study (2018–19) and after either one or two years of treatment for teachers, depending on when they joined the study. The teacher outcomes were the amount of instructional time teachers spent presenting new science information (in English) while (a) students performed an academic task and/or teachers evaluated the accuracy of student responses, and (b) the class was engaged in listening and/or speaking (as opposed to reading and writing).

Research Questions

1. What is the impact of LISTO on fifth grade students’ science and reading achievement after one year of treatment compared with the business-as-usual condition?
2. What is the impact of LISTO on fifth grade science teachers' instructional delivery after one or two years of treatment compared with the business-as-usual condition?
3. Was each key component of LISTO implemented with fidelity?
4. How do teachers perceive the effectiveness of the VPD, and do they perceive their practice to improve with reflections included in training?

5. How do teachers and coaches perceive the ease of use and quality of VMC using Hoot Education and APEXIS software and hardware?

Method

Sample

Prior to the 2017–18 school year, the grantee recruited 71 Texas schools in 37 school districts in which low-income students comprised more than 50% of the student population. Schools were randomized to either the treatment or control condition within district, whenever possible. For seven districts, schools were randomized to either treatment or control within district. For the remaining 30 districts, there was only one participating school per district, and schools were randomized to either the treatment or control condition. Table 1 shows the results of the random assignment of schools.

Table 1
Results of the school random assignment

	Total	Rural	Non-Rural
Treatment school *N*	35	23	12
Control school *N*	36	24	12
District *N*	37	33	4

Note. Two districts and three schools left the study prior to implementation due to changes in district administration.

Fifth grade science teachers in participating schools were then recruited to participate in the study. Initially, a maximum of two teachers per school were recruited to participate. Because a number of rural schools had only one fifth grade science teacher and there were fewer numbers of teachers than expected, ultimately, all fifth-grade science teachers in rural schools were offered participation in the study. In non-rural schools, up to two fifth grade science teachers were invited to participate in the study. Given teacher turnover, new teachers were also allowed to join the study after the start of the 2017–18 school year and through the beginning of the 2018–19 school year. One hundred twenty-one teachers participated in the study for 2017–18, 31 teachers joined the study in 2018–19, and 69 participated for two consecutive years. Students were exposed to the program in their fifth-grade year only.[6] This count reflects teachers who had non-missing student outcomes in either of the 2017–18 or 2018–19 school years or had at least one observation submitted in the 2018–19 school year. In the 2019–20 school year, 61 teachers participated, and 41 teachers participated in the final year, 2020–21.

For each school, up to four classes or rotations were selected to participate in the study. The grant could not support providing the intervention to all fifth-grade science classes in study schools. For schools with two fifth grade science teachers participating in the study, two classes or rotations per teacher were selected to participate in the study. For schools with more than two fifth grade science teachers participating in the study, one class or rotation per teacher was

[6] Some teachers were not included in the student and teacher impact analyses, however, due to missing data.

selected to participate. For schools where study teachers had only one class (e.g., not departmentalized), all of the teacher's students were included in the study.

Students were included in the study if they were in the sampled classes, and if their parents provided consent for them to participate in the study. The student sample was also narrowed to the students who had non-missing test scores on both the pretest and posttest. Similarly, teachers were included in the impact analyses on teacher outcomes when teachers had non-missing observational scores at both the pre- and post-intervention time points. Given potential bias due to non-random selection of participating teachers and students from study schools, baseline equivalence on the pretest measures for each analytic sample was assessed (WWC, 2020).

Table 2 outlines the characteristics of the teacher sample using data from the first two years of the study. Note that there were two teacher samples, one for the analyses on student outcomes, and a second for the analyses on teacher outcomes. LISTO and control teachers were relatively similar in terms of background characteristics, although background characteristics were unavailable for roughly one-third to one-half of participating teachers. There were no statistically significant differences in teacher characteristics between the LISTO and control groups for either teachers or their students. The statistical models controlled for alternative certification, as it appeared to be an explanatory covariate.

Table 2
Characteristics of the teacher sample, Years 1 and 2

	Analyses on Student Outcomes			Analyses on Teacher Outcomes		
Characteristics	Total	LISTO	Control	Total	LISTO	Control
Female	77.85%	80.00%	75.68%	73.58%	78.26%	70.77%
Science teacher	86.97%	89.86%	83.74%	95.35%	94.44%	96.00%
Certification Alternative	42.41%	43.24%	41.55%	46.15%	47.83%	44.83%
Science	9.85%	10.45%	9.23%	17.65%	17.39%	17.86%
ESL	29.55%	29.85%	29.23%	27.45%	30.43%	25.00%
Bilingual	28.79%	29.85%	27.69%	33.33%	39.13%	28.57%
Average years teaching	Total	LISTO	Control	Total	LISTO	Control
All	10.05	10.81	9.27	10.51	11.57	9.70
Science	6.26	6.24	6.27	7.85	8.96	6.97
5th grade	4.47	4.12	4.83	5.35	5.43	5.28
N	219	100	119	71	33	38

Notes. 1. Descriptive statistics for teachers were based on the analytic samples. Teacher characteristics for the student outcomes analyses were based on the combined analytic samples across the 2017–18 and 2018–19 school years. Teacher characteristics for the teacher outcomes analyses were based on the 2018–19 year only. 2. Teacher characteristics were missing for approximately one-third to one-half of teachers, depending on the characteristic and sample.

Next, we outline characteristics of the student sample, which included 5,180 students in Years 1 and 2, with an additional 932 in Year 4. Although 2,361 students were served in Year 3 no outcome data was available due to the COVID-19 pandemic interruptions in testing. As shown in Table 3, describing the students in Years 1 and 2, the majority (75.36%) of students were low-income, and about one-third (32.58%) were English learners (ELs). Additionally, the majority (73.67%) of students were identified as Hispanic or Latino, with smaller percentages of White (15.75%) and Black (7.42%) students. Therefore, the student sample reflected the grant priorities to serve low-income students, many of whom were ELs.

Table 3
Characteristics of the student sample, Years 1 and 2

Characteristics	Total (%)	LISTO (%)	Control (%)
Low-income	75.36	78.36	71.91
English learner (EL)	32.58	34.95	29.84
Reclassified EL	2.94	3.36	2.46
Migrant	2.44	2.53	2.33
Special education	7.84	7.69	8.02
504 plan	8.95	8.86	9.04
Female	49.96	49.61	50.38
Latino	73.67	72.92	74.54
White	15.75	15.54	16.00
Black	7.42	7.85	6.91
More than one race	2.46	3.48	1.28
Other race	0.70	0.20	1.28
N	5,180	2,790	2,390

Note. Descriptive statistics were calculated for the combined analytic sample across the 2017–18 and 2018–19 school years.

While LISTO and control students were similar in terms of demographic characteristics, there were a few small differences between the two groups of students. A larger percentage of LISTO students were low-income (78.36%) relative to control students (71.91%). In addition, a larger percentage of LISTO students were English learners (34.95%) compared with control students (29.84%). The statistical analysis controlled for all of these student characteristics, as well as baseline achievement.

Measures and Instruments

Student outcomes. The evaluation estimated the impact of LISTO on student performance in science and reading using the following assessments and instruments:

- *State of Texas Assessments of Academic Readiness (STAAR) Science* (Texas Education Agency, 2017a): The science test measures student knowledge of science concepts and scientific processes and is administered each spring to all students in Texas in the fifth and eighth grades. This test is primarily administered in English but was administered in Spanish to 0.40% of students in the study.

- *STAAR Reading* (Texas Education Agency, 2017b): The reading test measures grade-level reading expectations, including students' critical thinking, inferencing, making connections, understanding, and application in different genres of reading. STAAR Reading is administered each spring to all students in Texas in grades 3–8. The test was administered in Spanish to about 2% of students in the study.

- *Iowa Test of Basic Skills (ITBS) Science* (Dunbar & Welch, 2015): The science subtest measures student knowledge of science concepts. This test was administered to fifth grade students by trained testers,[7] in the fall and spring of each study year (e.g., both prior to program implementation and after one year of treatment).

- *Big Ideas in Science Assessment (BISA)* (Lara-Alecio et al., 2018): This instrument measures disciplinary core ideas in both the Next Generation Science Standards and Texas science standards. The instrument was developed by researchers at Texas A&M University and has internal reliability of 0.70 (Lara-Alecio et al., 2018). The instrument was administered to students in both the fall and spring of each study year.

- *Science interest survey:* This 5-point Likert scale instrument gauges student motivation and self-efficacy to learn science. It also contains science-related items about family encouragement, teacher efficacy, and English comprehension. The instrument was developed by researchers at Texas A&M University and was found to have an internal reliability of 0.86 (Tong et al., 2020). The survey was administered to students in both the fall and spring of each study year.

Student scores on the STAAR Science and Reading tests in spring 2019 served as the confirmatory contrasts. The remaining student assessments and assessments administered in spring 2018 were analyzed for exploratory purposes. For nearly all student outcomes, the same instrument was used as both the pretest and posttest measure. The one exception is that the pretest for STAAR Science was the ITBS Science test administered in the fall of fifth grade, since STAAR Science is not administered to students in the fourth grade.

LISTO project personnel at Texas A&M University were responsible for data collection, processing, and scoring. Data were then transferred to the CRRE evaluation team, and the evaluation team checked, merged, and analyzed the data.

Teacher outcomes. Teacher outcomes for this impact study were improved instructional delivery per pedagogical transitional bilingual theory. Teacher outcomes were assessed using the following instruments:

- *Science Teacher Observation Record (STOR)* (Lara-Alecio et al., 2012): The STOR was developed by researchers at Texas A&M University and documents the extent to which teachers implement best practices while teaching science content, particularly to ELs. The STOR asks raters to rate teachers on approximately 10 items that capture teacher preparation for and delivery of science instruction.[8] Topics included: teacher and material preparation; lesson pacing; technology utilization; questioning strategies; opportunities for student writing and reading in science; connections to prior knowledge; reading comprehension supports; use of scientific inquiry; and student reflection. The STOR used

[7] Testers were hired by CRRE and trained by LISTO project personnel.
[8] The inter-rater reliability of STOR was 0.86 (Lara-Alecio et al., 2012).

a 4-point scale in 2017–18 and a 5-point scale in 2018–19, and scores were created by CRRE.[9]

- *Transitional Bilingual Observation Protocol (TBOP)* (Lara-Alecio et al., 2009): The TBOP was previously developed and validated by researchers at Texas A&M University from the four-dimensional bilingual pedagogical classroom theory (Lara-Alecio & Parker, 1994). TBOP captures certain pedagogical behaviors (e.g., language of instruction, language content, activity structure, communication mode, English as a second language (ESL) strategies, etc.) during classroom instruction (Lara-Alecio et al., 2009; Tong et al., 2017b). The TBOP asks raters to record the frequency of such behaviors; therefore, the TBOP score denoted the proportion of instructional time the teacher demonstrated the particular behavior.[10] Frequency data were provided to the CRRE evaluation team by Texas A&M University, and CRRE calculated teachers' TBOP scores. TBOP scores were used to document changes in teacher practices over time. The two domains of interest for this study were the proportion of time the teacher spent presenting new science content while (a) teachers were overseeing students perform an academic task or evaluating the accuracy of student responses, and (b) teachers explicitly focused on academic oral language.

All teachers, treatment and control, were observed by trained observers three times annually and rated on both the TBOP and STOR instruments. LISTO project personnel were first extensively trained on the instruments by Texas A&M University researchers and then observed and scored teachers virtually using videos of classroom practice. Observations occurred at the beginning, middle, and end of the school years. The first round of observations occurred approximately 1-2 months after program implementation began, typically 1-2 weeks after completion of student consent and baseline assessments.

Teachers' TBOP scores and STOR ratings were not analyzed for the 2017–18 school year. Due to Hurricane Harvey, many teachers did not submit their instructional videos, and therefore, these data were missing for most teachers. Note, however, that the scores from fall 2017 were used as the pretest when not missing; otherwise, scores from fall 2018 were used as the pretest. Scores from the final observation in spring 2019 were used as the confirmatory contrast.

Perceived quality of the program. Perceived quality of the program was also captured by teacher perceptions about the professional development, curriculum materials, and coaching. Two qualitative data sources were used to capture teacher perceptions about program quality:

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[9] Scores were created by calculating the mean rating across all items. There were no item-level missing values for teachers who had non-missing STOR scores.

[10] Prior studies have found inter-rater agreement using the TBOP ranging from 0.65 to 0.98 in Kappa values (Bruce, Lara-Alecio, Parker, Hasbrouck, Weaver, & Irby, 1997; Breunig, 1998; Irby et al., 2007; Irby et al., 2010). However, given the multi-dimension-multi-rater nature of the instrument, a more rigorous process was developed to establish inter-rater reliability (IRR) using Gwet's (2012) AC_1 coefficient; the IRR using this approach ranged from .724 to .945 (Tong et al., 2017a).

- *Teacher surveys.* At the end of each school year, researchers at Texas A&M University administered online surveys to treatment teachers. Using a combination of Likert-type and open-ended questions, the survey asked teachers to rate their experiences with the Virtual Professional Development (VPD) sessions.

- *Teacher focus groups.* Texas A&M University researchers conducted virtual focus groups for treatment teachers in May of each school year. Facilitators used video conferencing software to conduct interviews that lasted approximately 45 minutes. The protocols asked teachers to provide their perceptions of LISTO on student engagement and academic development, as well as the quality of program curricula, professional development, and coaching.

Analytic Approach

Impact study. The impact of LISTO on student and teacher outcomes was estimated using hierarchical linear modeling. Propensity score weighting was also used to estimate program impacts on teacher outcomes due to large differences on the pretest measure.

Hierarchical linear modeling. The impacts of LISTO on student and teacher outcomes were estimated separately by school year. Due to Hurricane Harvey in the summer of 2017, the first year of LISTO implementation became more of a pilot year, and confirmatory contrasts were conducted on outcomes collected in spring 2019. Impacts of LISTO were estimated using a hierarchical linear model with students or teachers nested within schools (Raudenbush & Bryk, 2002). The model to estimate impacts of LISTO on student outcomes was as follows:

$$Y_{ij} = \gamma_{00} + \gamma_{01} treatment_j + \gamma_{10} pretest_{ij} + \gamma_{20} X_{ij} + \gamma_{02} Y_j + u_{0j} + r_{ij}$$

where:
Y_{ij}: Test score for student i in school *j*
γ_{00}: Grand mean for students in control condition
γ_{01}: Average treatment effect
$Treatment_j$: Treatment indicator for school *j*
γ_{10}: Regression coefficient for the pretest
$pretest_{ij}$: Pretest score for student i in school *j*
γ_{02}: Vector of regression coefficients for student covariates
X_{ij}: Vector of student covariates (outlined in the appendix)
γ_{02}: Vector of regression coefficients for the district dummy indicators
Y_j: Vector of district dummy indicators for school *j*
u_{0j}: Random school effect for school *j*
r_{ij}: Residual for student i in school *j*

The model to estimate the impacts of LISTO on teacher outcomes was identical to the one above, except that teachers (instead of students) were the unit of analysis. This model controlled for alternative certification of teachers and the pretest.[11] The independent variables, except for the treatment indicator, were grand mean centered to facilitate interpretation of the intercept (Enders & Tofighi, 2007).

For all models, students or teachers were included in the analysis if they had non-missing pretest and outcome scores. Students or teachers with missing background variables were included in the analysis, using a simple imputation method for missing values and dummy indicators (WWC, 2020).

Similar hierarchical linear models—without the covariates or district dummy indicators—were used to estimate baseline equivalence on each pretest measure for each analytic sample. Baseline equivalence was satisfied (≤ 0.25 standard deviations) for all student and teacher outcomes, after applying propensity score weighting for teacher outcomes (WWC, 2020).

Propensity score weighting. Baseline equivalence was not satisfied for the teacher analytic samples (> 0.25 standard deviations) because the pretests were collected after treatment had already begun. To account for these baseline differences, propensity score weighting was incorporated into the hierarchical linear model outlined above for teacher outcomes—both in models estimating program impacts and in models estimating baseline differences between treatment and control groups. Propensity score weighting was designed to make the weighted samples equivalent on the pretest measure (WWC, 2020).

To obtain the propensity score weights and calculate the average treatment effect for the treated (ATT), we first regressed the logit of treatment group assignment on the pretest. Then, propensity score weights were calculated using $weight = 1$ for the treatment group and $weight = \frac{probability}{1 - probability}$ where probability is the likelihood of being in the treatment group. Propensity scores and weights were determined separately for each outcome measure and analytic sample to achieve baseline equivalence.[12]

Implementation study. To determine whether LISTO was implemented with fidelity, we analyzed the percentage of teachers and schools who participated at high levels of fidelity in each of the key program components—virtual teacher professional development (VPD), virtual mentoring and coaching (VMC), and distribution of curricula materials (LIS). High fidelity was determined based on the criteria in Table 4.

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[11] For each teacher outcome, the pretest used the same instrument as the outcome but was administered at an earlier time point. The pretest was the score from fall 2017, and for Year 1 teachers with missing pretest data and all teachers who joined in Year 2, the pretest was the score from fall 2018. The only exception was for STOR; due to large baseline differences in LISTO and comparison teachers in fall 2018, only the pretest from fall 2017 was used.

[12] To incorporate propensity score weights into the hierarchical linear model, we used Stata with the [pweight=weight] option in the level-1 model. We also used Stata's svy command to calculate the means and standard deviations of the pretest and posttest scores.

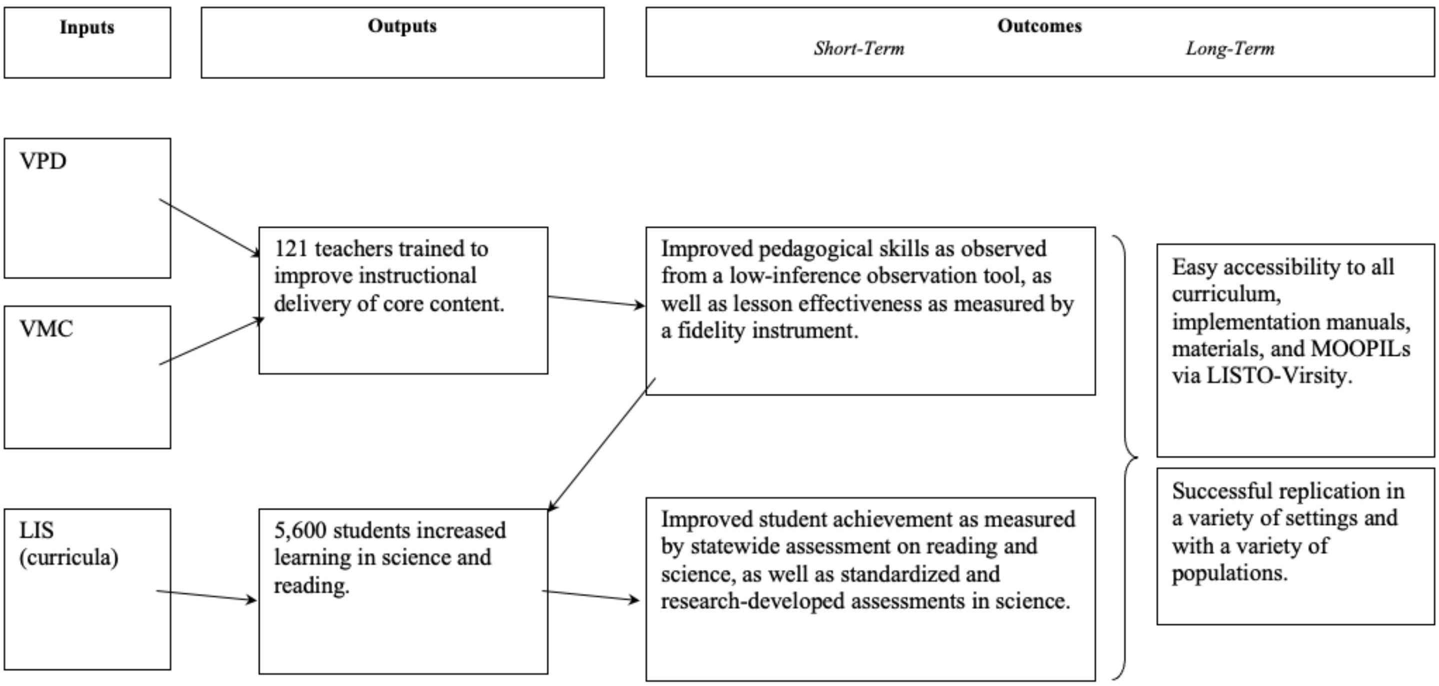
Table 4
Criteria for high fidelity of implementation

Key Program Component	Data Source	Definition of High Fidelity (Teacher Level)	Definition of High Fidelity (School Level)	Definition of High Fidelity (Sample Level)
Virtual Professional Development (VPD)	Teacher training attendance record	Teacher participates in at least 90% of PD sessions	100% of participating teachers have high fidelity	At least 90% of schools have high fidelity
Virtual Mentoring and Coaching (VMC)	Coach observation feedback rubric	Teacher participates in at least 90% of coaching sessions	100% of participating teachers have high fidelity	At least 90% of schools have high fidelity
Curricular Materials (LIS)	Delivery receipts	Teacher receives curriculum	100% of participating teachers receive curriculum	At least 90% of schools have high fidelity

Fidelity of VPD, VMC, and curricular materials were measured at the teacher, school, and sample levels. VPD was considered to have been implemented with fidelity in a school if all treatment teachers in the school participated in 90% of the professional development sessions offered. VMC was considered to have been implemented with fidelity in a school if all treatment teachers in the school participated in 90% or more of the coaching sessions offered. The distribution of curricular materials was considered to be implemented with fidelity if the school received the curriculum materials. At the program component level, 90% of schools had to have achieved high fidelity for the program component to be implemented with fidelity at the sample level.

The fidelity of implementation for each program component was analyzed separately for each school year. Teachers were excluded from the fidelity sample if (a) they did not attend any of the VPD training sessions; (b) they (or their schools) withdrew from the study; or (c) they left their schools. The key components of LISTO and how they theoretically relate to outcomes are detailed in the logic model, as shown in Figure 1.

Figure 1
LISTO logic model



There are three inputs: Virtual Professional Development (VPD), Virtual Mentor Coaching (VMC), and Curricular Materials. The output for VPD and VMC is to train 121 teachers to improve instructional delivery. The output for the curricular materials is to increase learning in science and reading for 5,600 students. The short-term outcomes are to improve pedagogical skills as observed from a low-inference observation tool, as well as lesson effectiveness as measured by a fidelity instrument. Improved student achievement as measured by statewide assessment on reading and science, as well as standardized and research-developed assessments in science is also a short-term outcome. Long-term outcomes include easy accessibility to all curriculum, implementation manuals, materials, and MOOPILs via LISTO-Virsity and successful replication in a variety of settings and with a variety of populations.

Qualitative data sources—treatment and control teacher surveys and treatment teacher focus groups—were analyzed thematically. The analyst initially reviewed the data, searching for recurring themes in participants' responses; these themes were cross-referenced with data from teacher surveys, and the findings were categorized and reported by theme.

Findings: Years 1-2

Program Impacts

The following program impacts should be interpreted cautiously due to the aforementioned limitations of delayed and incomplete implementation during the first year, as the baseline year of the project. LISTO resulted in increased teacher capacity to implement research-based strategies while teaching science content, yet this improvement did not necessarily translate into improved student achievement in science or reading. The professional development and coaching supplied treatment teachers with pedagogical strategies for teaching science, including those that have been shown to improve literacy and be particularly effective for ELs. Findings showed that LISTO teachers implemented these research-based pedagogical strategies to a greater extent than did control teachers. Despite a number of barriers to implementation, the LISTO intervention was directly responsible for benefitting teachers' instructional practices, especially those who implemented LISTO with more fidelity.

There was a statistically significant difference in science achievement on the STAAR science assessments for students in LISTO versus control classrooms in 2017–18. Students in LISTO classrooms also expressed slightly lower average interest in science than students in control classrooms. In 2018–19, students in LISTO classrooms had lower average science achievement on the state test than did students in control classrooms, as well as average lower BISA scores. However, qualitative data collected from treatment teachers suggested that students had improved science vocabulary as a result of LISTO participation, which led to improvements in student self-efficacy and engagement. There were no differences in reading achievement for LISTO and control students in either study year.

Science achievement. Fifth grade students in LISTO classrooms did not outperform similar, control peers on the state accountability science test (e.g., STAAR Science), or on formative science assessments (e.g., ITBS Science, BISA) in either the 2017–18 or 2018–19 school years. There was a statistically significant difference in science achievement between LISTO and control students in 2017–18 ($p < .05$) on the STAAR Science assessment, with LISTO students underperforming control students by about 48 points. LISTO students underperformed control students on the STAAR Science test in 2018–19 by roughly 73 points or -0.13 standard deviations ($p < .05$), but there were no statistically significant differences in student performance on formative science assessments in that year.

Table 5 shows the impacts of LISTO on student outcomes in science relative to control students. Specifically, the table outlines the unadjusted mean for the control students, impact estimate, standard error of the estimate (SE), *p* value of the impact estimate, and standardized effect size. The standardized effect size provides the effect of LISTO in terms of standard deviations.

Table 5
Estimated impacts of LISTO on science outcomes

Outcome	**Unadjusted control mean**	**Impact estimate**	**Standard error**	***p* value**	**Std. effect size**
2017–18					
STAAR science	3841.79	-48.15*	24.50	0.049	-0.10
ITBS science	213.64	-0.90	1.56	0.566	-0.03
BISA	19.92	-0.17	0.29	0.548	-0.03
Science interest	3.19	-0.07*	0.03	0.012	-0.14
2018–19					
STAAR science	3904.85	-72.67*	35.58	0.041	-0.13
ITBS science	213.28	-2.15	1.78	0.226	-0.07

BISA	17.17	-0.34	0.41	0.413	-0.06
Science interest	3.08	-0.02	0.02	0.285	-0.06

Note. *p<.05.

LISTO students had slightly lower average interest in science (determined by a student survey) than control students in 2017–18 by 0.07 points on a 5-point survey scale, or -0.14 standard deviations ($p < .05$). There was no statistically significant difference in science interest between LISTO and control students in 2018–19. Across both years, there was a statistically significant difference in science achievement for LISTO and control students. Directionally, results generally showed negative program effects in science achievement and interest.

Outcomes collected in the 2017–18 school year were considered to be exploratory, given the timing of Hurricane Harvey, which hit Texas in August of 2017. Outcomes in the 2018–19 school year served as the confirmatory contrasts. In both school years, students were exposed to the program through their teachers in only their fifth-grade year. One year of exposure for students may have been insufficient to increase student achievement in science.

Science vocabulary. While quantitative data did not yield positive impacts of LISTO on students' science achievement, qualitative data collected from LISTO teachers via focus groups and interviews indicated that teachers believed students had improved in their knowledge of science vocabulary as a result of participating in LISTO. The most frequently cited response from teachers was that LISTO directly impacted the way that students talk about science both academically and conversationally. Specifically, the literacy component of LISTO provided students with a common language that included grade-level, aligned, academic scientific vocabulary terms. Prior to this, one teacher explained, "They know what's happening outside, but they don't realize that it is actually related to science. They see the rain, but they don't realize it's a process." In turn, the literacy component "…is a big deal because it helps make the connection from what they're seeing to text." By experiencing science through a narrative lens—that is, learning about scientific concepts and vocabulary through reading activities— students were able to grasp concepts in more authentic ways that were meaningful.

LISTO teacher respondents also noted that the literacy-infused strategies improved students' scientific writing. One teacher noted that students gradually integrated scientific vocabulary into their writing, "…almost two times more often than my other two [non-LISTO] classes," and that this progression in writing "…just started to become natural." The literacy-infused instruction helped students to elaborate in their writing, as observed by one teacher: "I saw my students adding a whole lot more detail and more explanation than they used to know, and they would use the correct academic vocabulary." Some teachers found problems with the LISTO vocabulary, saying that it was "too advanced," and that students had difficulty connecting the reading passages with the vocabulary terms. Still, teachers generally acknowledged the benefits of literacy-based science instruction with a focus on science vocabulary, particularly for struggling readers.

Reading achievement. Improving student literacy was another focus of LISTO, in addition to increasing students' science achievement. There were no statistically significant differences between LISTO and control students on the state reading assessment (e.g., STAAR) in either school year. Directionally, LISTO students had higher average scores on STAAR

Reading than control students, controlling for student characteristics, but these differences were small and not statistically significant.

As shown in Table 6, LISTO students had higher STAAR Reading achievement by an average of 2.65 points in 2017–18 and 4.09 points in 2018–19. The standard errors of these estimates were large, and therefore, these differences were not statistically significant. The differences translated into effect sizes of +0.02 in 2017–18 and +0.03 in 2018–19.

Table 6
Estimated impacts of LISTO on reading outcomes

Outcome	**Unadjusted control mean**	**Impact estimate**	**Standard error**	***p* value**	**Std. effect size**
2017–18					
STAAR reading	1558.46	2.65	5.01	0.597	0.02
2018–19					
STAAR reading	1564.06	4.09	5.73	0.476	0.03

Note. There were no statistically significant differences.

As noted above, outcomes from the 2017–18 school year were exploratory, given the timing of Hurricane Harvey, and outcomes in the 2018–19 school year served as the confirmatory contrasts.

The qualitative interview and focus group data indicated that numerous LISTO teachers found that the program instilled confidence in reading for their struggling readers. LISTO introduced new approaches to teaching reading, such as placing an emphasis on the features of a text. Some teacher comments included:

> *The biggest change I saw was the reading with confidence.*
>
> *I have very low, struggling readers… They don't like to read in front of anybody, but because they were paired up…they were eager to read and work together… They really enjoyed it.*
>
> *Even my low students, who were embarrassed to read in front of the class before [LISTO] – it helped them out a lot.*
>
> *[LISTO] really helped my low readers.*

Clearly, the literacy-infused strategies had a distinguished effect on struggling readers, but teachers found that advanced readers also favored the science-related readings over a traditional science textbook. In sum, teachers indicated that LISTO improved the confidence of struggling readers, as well as increased engagement in reading for all students.

Teacher outcomes. With teacher outcomes the primary goal of LISTO, the evaluation team analyzed program impact on teachers' instructional delivery and found improvements in teachers' capacity to implement research-based strategies while teaching science content. Specifically, LISTO teachers outperformed control teachers by 0.45 points (out of 5 points) on the STOR instrument ($p < .05$), which translated into an effect size of +1.12. These findings indicate that of the teachers who participated in two continuous years (both treatment and control), the treatment teachers yielded increased quality of science lesson delivery (e.g., teacher and material preparation; lesson pacing; technology utilization; questioning strategies; opportunities for student writing and reading in science; connections to prior knowledge; reading comprehension supports; use of scientific inquiry; and student reflection). Due to impacts of Hurricane Harvey and issues with teachers submitting the first round of classroom observations, there was a low return on the first round of classroom observations during Year 1; therefore, this finding should be interpreted with caution, given the relatively small sample size of eight LISTO teachers and 22 comparison teachers. However, there were no significant differences between LISTO and control teachers' focus on academic tasks, student feedback, or oral language when presenting new science content. Table 7 outlines these findings.

Table 7
Estimated impacts of LISTO on teacher outcomes

Outcome	**Unadjusted control mean**	**Impact estimate**	**Standard error**	**p value**	**Std. effect size**
2018–19					
TBOP (share of instructional time spent teaching new science content while students performed academic task or received feedback)	0.10	-0.02	0.04	0.549	-0.20
TBOP (share of instructional time spent teaching new science content with an explicit focus on oral language)	0.22	-0.05	0.07	0.469	-0.27
STOR (research-based practices when teaching science)	2.70	0.45	0.18	0.012	+1.12*

Notes. 1. All models also incorporated propensity score weighting to establish baseline equivalence. Treatment teachers were exposed to the intervention prior to the baseline measure. 2. *$p < .05$.

Program impact on teacher outcomes was estimated for the 2018–19 school year only. While teacher outcomes were collected during the 2017–18 school year, the response rate was low due to Hurricane Harvey. Therefore, teacher outcomes for the first year of implementation were not analyzed as part of the study.

Fidelity of Program Implementation

LISTO included three major program components: virtual professional development (VPD), virtual mentoring and coaching (VMC), and literacy-infused science using technology opportunities curricula (LISTO). The VPD and VMC components were made available to all participating treatment teachers. Fidelity of VPD, VMC, and curricular materials were each measured at teacher, school, and component levels (see Table 4). High fidelity for each program component was defined at the sample level and if 90% of participating schools had high fidelity, as outlined in Table 4.

Programmatic fidelity was measured in this study via VPD and VMC fidelity as determined by teacher attendance rates, and programmatic fidelity of implementation was measured by the timely acquisition and delivery of curricular materials as determined by delivery receipts of materials. At the individual teacher level, participation in VPD and VMC failed to meet the fidelity threshold in either year of program implementation (2017–18 or 2018–19). Overall, program fidelity could not be achieved because of a lack of observation data and delayed onset of all components of the intervention due to the effects from Hurricane Harvey. Between 77-80% of teachers participated with high fidelity in the VPD, and between 70-74% of teachers participated in the VMC with high fidelity. Similarly, at the school level, VPD and VMC also did not meet the teacher attendance threshold of fidelity in either year of program implementation. Between 62-72% of schools had high fidelity of participation in the VPD, and between 54-73% of schools had high fidelity of participation in the VMC, depending on the school year. These percentages fell short of the high-fidelity criterion for these two key program components VPD and VMC. The delivery of curricular materials was met with high fidelity in both of the 2017–18 and 2018–19 school years, however. Therefore, this key program component (LIS) was implemented with fidelity in both study years. Table 8 summarizes the fidelity for each program component by implementation year.

Table 8
Fidelity of implementation for each of the three components

Implementation Year	Key Component	Sample Size	Fidelity Score	Implemented With Fidelity?
2017-18	VPD	44 teachers	80%	N
		32 schools	72%	N
	VMC	42 teachers	74%	N
		33 schools	73%	N
	LIS	32 schools	100%	Y
2018-19	VPD	33 teachers	77%	N
		26 schools	62%	N
	VMC	30 teachers	70%	N
		24 schools	54%	N
	LIS	26 schools	100%	Y

The low levels of teacher participation in VMC and VPD might be explained in Year 1 due to a highly disruptive weather event, Hurricane Harvey, which interrupted the school year and likely impacted program fidelity. However, Year 2 saw an even further decline, particularly in the school level of teacher participation in VMC and VPD; taken together, the low levels of implementation at the teacher and school levels might be an explanatory factor in the results of the first two years of the LISTO program.

Perceived Program Quality

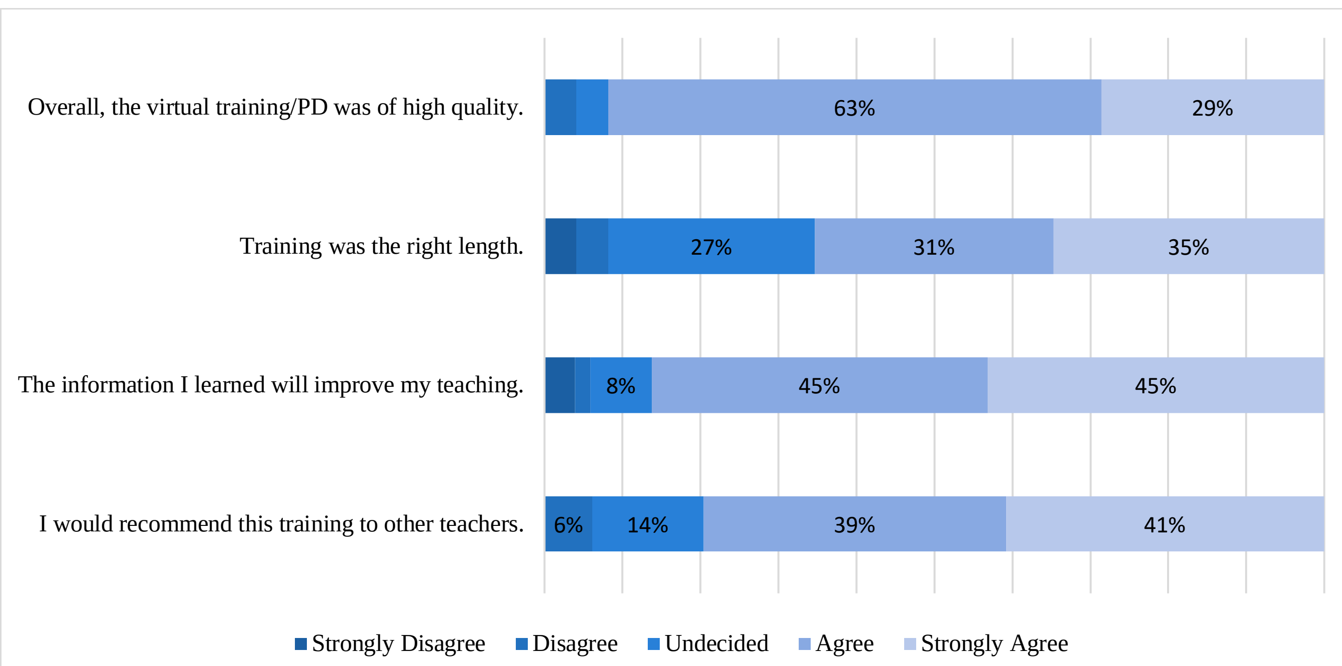
Teacher focus groups and interviews were conducted, and teacher surveys were administered in order to understand teacher perceptions of LISTO, and the professional development and coaching associated with it. Treatment teachers were also asked to identify various challenges with implementing LISTO and provide recommendations for program improvement. The focus group and interview protocols differed slightly between Year 1 and Year 2 cohorts, but generally, the participants were asked to comment on their personal experiences with LISTO professional development and coaching; the perceived benefits that LISTO had on their teaching practices and on student learning, specifically with regard to the observable changes in student confidence; and engagement in science. The following sections summarize teacher responses.

Professional development and coaching. Overall, teachers responded positively to the virtual professional development (VPD) opportunities. Ultimately, 98% (*n* = 49) of Year 1 teachers and 92% (*n* = 37) of Year 2 teachers surveyed reported that the VPD either met or exceeded their expectations, as shown in Figures 2 and 3. The VPD sessions, according to teachers, helped to create a more collaborative environment in which other teachers could watch and learn from their LISTO colleagues. One teacher respondent stated:

> *What I liked about the large group VPD… as teachers, we rarely have the opportunity to actually do and see another colleague teach because we are busy teaching our own classes. We were able to see, 'I'm not the only one in this, and I'm not alone.'*

The professional development sessions fostered a sense of community and camaraderie among teachers. This led to an environment where teachers felt "very supported." In particular, the majority of teachers in Year 2 (62%, *n* = 23) were in agreement that they felt a relationship with others participating in the VPD.

Figure 2
Teachers' perceptions of the VPD (n =49) in Year 1

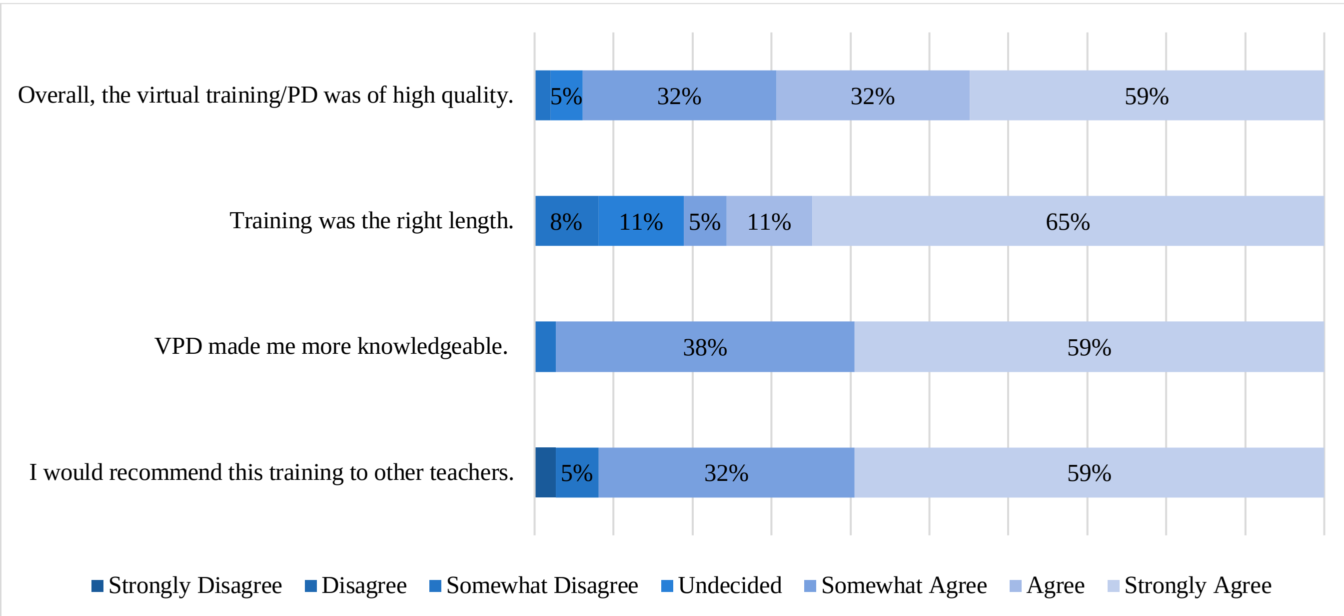


Note. Values < 5.0% are not labeled.

Teachers rated the VPD on a 5-point Likert scale where 1 = strongly disagree; 2 = disagree; 3 = undecided; 4 = agree; and 5 = strongly agree. The results follow:

- Overall, the virtual training/PD was of high quality: 63% agree; 29% strongly agree
- Training was the right length: 27% undecided; 31% agree; 35% strongly agree
- The information I learned will improve my teaching: 8% undecided; 45% agree; 45% strongly agree
- I would recommend this training to other teachers: 6% disagree; 14% undecided; 39% agree; 41% strongly agree

Figure 3
Teachers' perceptions of the VPD (n =37) in Year 2



Notes. 1. Values < 5.0% are not labeled. 2. The Likert-type scale used in Year 2 differed from the Year 1 scale, adding the options of "Somewhat Agree" and "Somewhat Disagree."

Teachers rated the VPD in Year 2 on a 7-point Likert scale where 1 = strongly disagree; 2 = disagree; 3 = somewhat disagree; 4 = undecided; 5 = somewhat agree; 6 = agree; and 7 = strongly agree. The results follow:

- Overall, the virtual training/PD was of high quality: 5% undecided; 32% somewhat agree; 32% agree; 59% strongly agree
- Training was the right length: 8% somewhat disagree; 11% undecided; 5% somewhat agree; 11% agree; 65% strongly agree
- VPD made me more knowledgeable: 38% somewhat agree; 59% strongly agree
- I would recommend this training to other teachers: 5% somewhat disagree; 32% somewhat agree; 59% strongly agree

Although the virtual togetherness was beneficial for teachers, many of them found issues with the VPD component, namely, the time demand and the relevance of the sessions. Several teachers commented that the VPD sessions felt too lengthy at times and often took place at the end of an already exhaustive school day. According to one respondent:

> *As a classroom teacher it is difficult to extend my day even further for a PD. I at times felt tired and sometimes disconnected depending on what happened that day.*

Another qualm with the VPD sessions centered on relevance. As teachers represented districts across the state in this large-scale study and followed their district-specific academic calendar and pacing, the science topic of the VPD may not have aligned exactly to what all participating teachers were implementing at a specific time. However, teachers did have access to recorded VPD and other support materials, so relevancy was mostly subjective and not a typical complaint from teachers. In sum, teachers saw more value in the VPD when it covered a topic that they were presently teaching.

Others appreciated the flexibility and convenience of the virtual trainings, with one teacher stating that "Virtual training is time effective." Compared to face-to-face trainings, most participants in Year 2 found the VPD better in terms of convenience of timing (78%, n = 29) and location (97%, n = 36), interaction with colleagues and mentors (68%, n = 25), and ongoing connections to their own classroom practices (89%, n = 33). Based on teacher feedback, Year 2 VPD sessions were reduced from 90 minute to 60-minute sessions. Further, the VPD sessions were recorded so that teachers could go back and review if needed.

Teachers also responded very favorably to the virtual mentor coaching because of its individualized approach and the useful feedback that they received from coaches. The overwhelming majority of LISTO teachers found VMC beneficial. As stated by one teacher, "Coaching feedback was excellent; I would have loved to have had them in my ear more." Still, as with the VPD, the single most common dissatisfaction was the demand that VMC placed on teachers' time, particularly at the end of the school day: "[Virtual coaching] was quite a bit long when we have long days."

Participants in Year 2 responded to questions specifically aimed at the improvements made to the curriculum and support that occurred between Years 1 and 2. The vast majority of teachers reported that their experience was either better, somewhat better, or much better compared to the previous year in all areas, including: vocabulary supports; reading passages and guides; using Nearpod as a delivery mechanism and as formative assessment; student engagement; support videos; monthly progress reports; participation checklists; and flex days.

Despite the general positivity towards VPD and VMC experiences and content, some teachers noted having technological issues. Many reported problems—including connectivity, hardware malfunctions, and an initial unfamiliarity with the software—that impacted the virtual experiences in negative ways. Although some LISTO teachers indicated that the VPD and VMC were time-consuming because of their duration and frequency, the sessions were not always relevant, and technological issues persisted, the overwhelming majority of teachers agreed with the sentiment that "the benefits outweighed the challenges."

Curricula materials. Teachers overwhelmingly agreed that LISTO strongly influenced the pedagogical landscape in their classrooms through literacy- and technology-infused strategies. One of the greatest benefits for LISTO teachers was the curricular materials, and first-year teachers benefited the most. According to one,

> *The thing I liked…is having all the supplies; I don't really have to plan a lot. It's handed to me, and as a first-year teacher…I don't have to spend all weekend long planning what I'm going to do.*

LISTO essentially supplied an instructional playbook for teachers; this helped assuage the uncertainty of first-year teaching and provided a structural framework for the class, where it previously might not have existed. A common refrain among teachers was that "I've learned to pace myself [with] more structure than what I had before."

As mentioned previously, the subcomponent of SRM^2 was not implemented during the first year of the project. The intent of this component was to have university scientists meet via live, synchronous, online sessions with students; however, during the second year of the project, the interaction was limited to pre-recorded video clips embedded into lesson presentations and opportunities for students to pose questions and scientists to respond. Teachers pointed out that the students found the SRM^2 component ineffective, saying it was difficult to make a connection with mentors through video, and this undercut the value of mentorship. Some specific comments included:

> *I don't think the kids really saw [the videos] too much as mentors because I guess it was just like a video that they watched, you know, like any other thing they would watch on YouTube or things like that…I mean the videos were interesting, you know, but I don't think the kids saw them as mentors just, you know, scientists that were there somewhere far away.*

> *They kind of didn't connect…That's really not that far from where I am. It was just kind of 'oh, it's another adult on the screen, you know telling me something.' They didn't connect it to a mentor.*

This view was consistently reinforced by other teachers, who acknowledged that while the videos were interesting, they did not achieve the intended effect of mentoring students. This likely decreased their effectiveness, or at the very least, reshaped their usefulness in the classroom.

Similarly, teachers gave mixed reviews on the FIS take-home science kits. The expectation was that all treatment teachers send home FIS booklets and send home GoVision glasses with consented students only to record family interactions while working through the activities. During the second year of the project, 18 treatment teachers returned 251 microSD cards from the GoVision glasses. An end-of-the-year family survey (n = 82) reported that 85% of families considered the FIS family activities fun, 91% considered the activities a valuable learning experience, 84% reported that FIS activities helped the family engage in science-related conversations, and 87% reported the learner's (student's) attitude toward science improved. Some teachers cited low levels of participation due to limited family involvement, a lack of time, and because the activities were optional. A small number of teachers described the familial involvement with the science kits as "disappointing" and "disengaged." Others described more barriers to home implementation of the science kits because households lacked the necessary materials (such as ice trays) or because parents objected to the idea of introducing recording devices into the home. Perhaps a more common rationale was that the science kits took a backseat to preparing students for the STAAR test. Still, most teachers gave positive feedback on the science kits, finding that the activities were educational but "a different kind of homework." The family involvement science kits were successful for those students and families who embraced them. A teacher respondent summarized the general sentiment towards LISTO saying, "There may be some difficulties, but it is an overall excellent program."

Perceived program benefits for teachers. Teachers identified numerous benefits that LISTO had on their instructional practices. Most commonly, respondents valued the LISTO program as being a "roadmap" for learning. The curriculum and materials that were provided helped teachers (and students) clearly understand where they were and where they were headed by articulating clear goals and objectives. This helped teachers to "see the bigger picture." Other benefits of LISTO included the ability to identify struggling learners earlier on and the provision of materials for teachers.

Some respondents commented further:

> *[LISTO] gave you a map so that you could work your way through the lessons really easily and it lets you know exactly where you were going with each lesson. You could follow it to know what the kids should know at the end of the lesson.*
>
> *[LISTO] definitely helps you on track sort of like where you get help on exactly where you are at. We can look at what we should be able to do and when exactly you will be done.*
>
> *I love that they had a big picture idea, but they had little pieces for the kids to connect to get the education out of it.*
>
> *It has helped me a lot with being able to apply those higher order thinking questions towards my students.*
>
> *I definitely appreciated having all of the material. And all the supplies. Because that's always been a huge issue with us.*

Perceived program benefits for students. Teachers indicated that LISTO provided benefits to students in terms of engagement and confidence with regard to science-based content. Teachers attributed the increased interest in science directly to LISTO strategies and to the associated technology. One teacher reported that "There [was] definitely a change in the enthusiasm for learning science when they got to use the technology." In short, instructional technology promoted student engagement with the content. Technology also democratized student participation; one teacher recalled, “I saw a big change in my quiet kids. There was no hiding in class anymore.” Technology provided more reserved students with greater opportunities to participate than the traditional call-and-respond lecture style allows for, and therefore improved overall engagement.

In addition, numerous teacher respondents said that their students were excited to go home and talk to their parents about what they learned in science that day. Collectively, teachers agreed that because of LISTO, “[students] were more excited, they were more interested, they were more positive.” These changes were most noticeable in lower-performing students. According to two teacher respondents:

> *It was a great experience to see [students] grow and really become passionate about science.*
> *It’s been wonderful to see in our lower students how much more confident they are.*

Multiple teacher respondents recounted that the newfound interest in science and the resulting increase in content knowledge translated into learner confidence. A LISTO teacher summed up the change in their students’ mindset towards science: “[T]he students felt more confident, they had more knowledge, and they were more interested in the subject.” LISTO also empowered students, with one teacher stating, “They’re not afraid of taking risks anymore.”

Barriers to implementation. The implementation of LISTO was not without its challenges, however. An emergent theme from teacher responses included issues with the pacing of LISTO. Despite respondents (predominantly first-year teachers) who appreciated the structure of the curriculum provided to them, many found the pacing to be the “hardest part” of LISTO, specifically noting that there was “not enough time for review.” Other teachers elaborated:

> *We never really had time to finish everything.*
>
> *At the end, you really had to pick and choose because you were running out of time.*
>
> *I really appreciated when [LISTO] backed off of the expectations to put so many activities in; I felt stressed when I couldn’t get to them.*

Although time constraints affected the pacing of LISTO, teacher participants in their second year remarked that it had improved substantially from the first year.

In addition to the time management issue, teachers experienced a variety of technological setbacks, which also may have impacted the quality of implementation. LISTO teachers reported issues with their personal technologies, which impacted their VPD and VMC sessions. These issues included, but were not limited to, audio and Bluetooth connectivity used specifically during VMC, and lagging internet connections at home and at school that challenged use of online software and student use of tablets in the classroom. Consequently, teachers expressed frustration in these areas, and this was reflected in the focus group interviews and teacher surveys.

The LISTO-issued technology devices presented some issues. Aside from the physical challenges and degradation of the tablets (e.g., broken screens, missing chargers, etc.), many teachers noted that the school's internet connectivity caused serious lag time issues, which prevented some content from loading. In response, LISTO project managers replaced devices and chargers once teachers notified project personnel and also worked with district/campus IT support to offer improved Wi-Fi service (e.g., via router or MiFi device). Consequently, several teachers reported that they instead used the school-provided devices (e.g., iPads that campuses already had integrated in their classrooms before LISTO) instead of LISTO-issued tablets. Each teacher had a unique set of difficulties with regard to technology—some more than others—and this likely informed perceptions of the LISTO program, overall. Still, support for LISTO remained overwhelmingly strong.

Recommendations for improvement. LISTO teacher participants in the focus groups were asked to provide recommendations for program improvement. The following recommendations were the most frequently cited. For the most part, these recommendations were not unpacked further, in terms of their justification or rationale. Regardless, these recurring themes provide valuable insights for program improvement:

- Begin the LIS lessons at the start of the school year rather than introducing them later in the semester. Whereas, due to research required student consent and baseline student testing processes, LIS lessons typically started 4-6 weeks into the fall semester. Teachers felt that students should be introduced to LIS lessons from the beginning in order to establish and uphold expectations for the remainder of the school year.
- Include more dynamic types of assessments besides quizzes. Teachers expressed a desire for more creative and diverse assessment options, even if informal.
- Offer more synchronous options for connecting students with scientists in order to improve the authenticity.
- Dilute the number and complexity of vocabulary words and provide the ability for teachers to add new vocabulary. Teachers requested that blank cards be added to the vocabulary sets so that they can add relevant terms as they see fit. Additionally, some teachers felt that some of the vocabulary words were too advanced and that they might not align with appropriate reading levels.
- Consider laptops in lieu of tablets, as they provide more functionality and are less fragile.

As challenges are expected with any large-scale implementation of a program, these issues are opportunities for program improvement.

Findings: Years 3-4

It is important to note that, due to the COVID-19 pandemic, in Year 3, only BISA, ITBS Science, and science interest survey scores were collected and only in the fall of the 2019–20 school year. STAAR Science and Reading scores were not collected during Year 3 (2019–20). Thus, the only contrasts we were able to conduct on student achievement were those focusing on Year 4 administrations of STAAR Science and Reading, BISA, ITBS Science, and the science interest survey. In terms of teacher measures, STOR and TBOP were administered in the fall and winter of Year 3, and fall, winter, and spring of Year 4. Thus, winter STOR and TBOP will serve as Year 3 teacher outcomes, while spring STOR and TBOP will serve as Year 4 teacher outcomes. Importantly, Year 4 ITBS and science survey data included data regarding assessment modality (paper vs. online). This variable was included in all analyses. BISA and STAAR assessments were all administered on paper, so this variable was not included in the analysis.

Program Impacts

Fifth grade students in LISTO classrooms did not outperform similar, control peers on formative science assessments (e.g., ITBS Science, BISA) in the 2020–21 school year. Table 9 shows the impacts of LISTO on student outcomes in science relative to control students. Specifically, the table outlines the unadjusted mean for the control students, impact estimate, standard error of the estimate (SE), *p* value of the impact estimate, and standardized effect size. The standardized effect size provides the effect of LISTO in terms of standard deviations. It is important to note that considerably fewer schools (and students) provided achievement data for Year 4 analyses, with only 27 schools providing science survey data, 26 schools providing BISA data, and nine schools providing ITBS data. STAAR Science analyses used BISA data as pretest scores to adjust for prior achievement, as no prior year STAAR Science scores were available and the BISA sample was a much more complete and more representative sample than the ITBS sample in Year 4. ITBS and BISA scores correlated similarly with STAAR scores.

Table 9
Estimated impacts of LISTO on science outcomes, Year 4

Outcome	**Unadjusted control mean**	**Impact estimate**	**Standard error**	***p* value**	**Std. effect size**
2020-21					
STAAR Science	3815.28	52.74	121.32	0.664	0.11
ITBS Science	213.77	–6.30	9.41	0.503	–0.20
BISA	16.53	0.11	1.10	0.922	0.02
Science interest	3.47	–0.10	0.11	0.360	–0.14

Note. ITBS Science, BISA, and the science interest survey were only administered in the fall of Year 3 (2019-20), and thus, no contrasts were conducted on student achievement in Year 3.

Directionally, results generally showed null or negative program effects in science achievement and interest. LISTO students had slightly lower average interest in science (determined by a student survey) than control students in 2020–21 by 0.10 points on a 5-point survey scale, or -0.14 standard deviations. There were no significant differences between groups on the three measures of science achievement in 2020–21, as measured by the STAAR Science, ITBS Science, and BISA assessments. Compared to control students, LISTO students scored slightly higher on the STAAR Science assessment of science achievement (52.74 points, or 0.11 standard deviations) and the BISA assessment (0.11 points, or 0.02 standard deviations), but these differences were not statistically significant ($p < .05$).

No science or reading achievement data were collected in Year 3, meaning that no confirmatory contrasts were conducted that year in student achievement. In all school years, students were exposed to the program through their teachers in only their fifth-grade year. One year of exposure for students may have been insufficient to increase student achievement in science, on any of the student achievement outcomes collected in this study.

Reading achievement. Improving student literacy was another focus of LISTO, in addition to increasing students' science achievement. In Year 4, there was no statistically significant difference between LISTO and control students. Directionally, LISTO students had lower average scores on STAAR Reading than control students, controlling for student characteristics, but these differences were not statistically significant ($p < .05$). Similar to the science assessments, it should be noted that STAAR Reading score analyses were limited to the 23 schools which provided BISA data (and STAAR data) because BISA data was also used as the pretest in this analysis. Due to the pandemic, prior year STAAR Reading scores were not collected and thus not available as a pretest.

As shown in Table 10, LISTO students had lower STAAR Reading achievement by an average of 0.82 points in 2020–21. The standard error of this estimate was large, and therefore, the difference was not statistically significant ($p < .05$). The difference translated into an effect size of –0.01.

Table 10
Estimated impacts of LISTO on reading outcome, Year 4

Outcome	Unadjusted control mean	Impact estimate	Standard error	*p* value	Std. effect size
2020-21					
STAAR Reading	1539.55	–0.82	38.92	0.983	–0.01

Note. There were no statistically significant differences.

Teacher outcomes. Table 11 outlines the findings of teacher outcome analyses. These analyses are similar to those performed in Years 1 and 2, with separate analyses conducted for outcomes from Year 3 and Year 4. LISTO teachers showed significantly greater gains on STOR in both Years 3 and 4, in relation to teachers in control schools ($p < .001$). The gains were 0.60 points greater in Year 3 and 0.41 points greater in Year 4 (out of 5 points), which translated into standardized effect sizes of 1.49 and 1.24, respectively. However, there were no significant differences between LISTO, and control teachers' focus on academic tasks, student feedback, or oral language when presenting new science content. Caution should be used in interpreting these effects, given the relatively small sample sizes used in these analyses, most notably in the Year 4 analyses.

Table 11
Estimated impacts of LISTO on teacher outcomes

Outcome	Unadjusted control mean	Impact estimate	Standard error	*p* value	Std. effect size
Year 3					

Outcome	Unadjusted control mean	Impact estimate	Standard error	*p* value	Std. effect size
TBOP (share of instructional time spent teaching new science content while students performed academic task or received feedback)	0.11	0.03	0.04	0.482	+0.19
TBOP (share of instructional time spent teaching new science content with an explicit focus on oral language)	0.20	0.03	0.05	0.602	+0.136
STOR (research-based practices when teaching science)	2.62	0.60	0.12	<.001	+1.49***
Year 4					
TBOP (share of instructional time spent teaching new science content while students performed academic task or received feedback)	0.11	0.09	0.07	0.177	+0.52
TBOP (share of instructional time spent teaching new science content with an explicit focus on oral language)	0.09	-0.00	0.06	0.981	-0.01
STOR (research-based practices when teaching science)	2.68	0.41	0.11	<.001	+1.24***

Notes. 1. Models using STOR as the outcome variable incorporated propensity score weighting to establish baseline equivalence. 2. Treatment teachers were exposed to the intervention prior to the baseline measure. 3. ***p<.001.

Fidelity of Program Implementation

LISTO included three major program components: virtual professional development (VPD), virtual mentoring and coaching (VMC), and literacy-infused science using technology opportunities curricula (LISTO). The VPD and VMC components were made available to all participating treatment teachers. Fidelity of VPD, VMC, and curricular materials were each measured at teacher, school, and component levels (see Table 4). High fidelity for each program component was defined at the sample level and if 90% of participating schools had high fidelity, as outlined below in Table 12.

Programmatic fidelity was measured in this study via VPD and VMC fidelity as determined by teacher attendance rates, and programmatic fidelity of implementation was measured by the timely acquisition and delivery of curricular materials as determined by delivery receipts of materials. At the individual teacher level, participation in VPD and VMC failed to meet the fidelity threshold in either year of program implementation (2019–20 or 2020–21). In Years 3–4, between 56-69% of teachers participated with high fidelity in the VPD, and between 86-88% of teachers participated in the VMC with high fidelity; this participation rate was higher than the first two years of the study. Similarly, at the school level, VPD and VMC also did not meet the teacher attendance threshold of fidelity in either year of program implementation. Between 25-69% of schools had high fidelity of participation in the VPD, and between 47-69% of schools had high fidelity of participation in the VMC, depending on the school year. These percentages fell short of the high-fidelity criterion for these two key program components VPD and VMC. The delivery of curricular materials was met with high fidelity in both of the 2019–20 and 2020–21 school years, however. Therefore, this key program component (LIS) was implemented with fidelity in all four study years. Table 12 summarizes the fidelity for each program component by implementation year.

Table 12
Fidelity of implementation for each of the three components

Implementation Year	Key Component	Sample Size	Fidelity Score	Implemented with Fidelity?
2019-20	VPD	35 teachers	69%	N
		16 schools	69%	N
	VMC	32 teachers	88%	N
		16 schools	69%	N
	LIS	32 schools	100%	Y
2020-21	VPD	38 teachers	56%	N
		16 schools	25%	N
	VMC	28 teachers	86%	N
		15 schools	47%	N
	LIS	26 schools	100%	Y

Perceived Program Quality

In Year 3, teachers (*n* = 25) responded to the VPD online survey and focus group interviews were conducted; in Year 4, teachers (*n* = 31) participated in individual interviews, but the VPD survey was not administered since the program developers were looking towards sustainability instead. The survey, focus groups, and individual interviews were designed to better understand teacher experiences with LISTO and their perceived perceptions of the impact of LISTO on their teaching and on student achievement, to investigate challenges and barriers to implementation, and to seek recommendations for program improvement. The focus group and interview protocols differed slightly in Year 2, though the general aim remained the same.

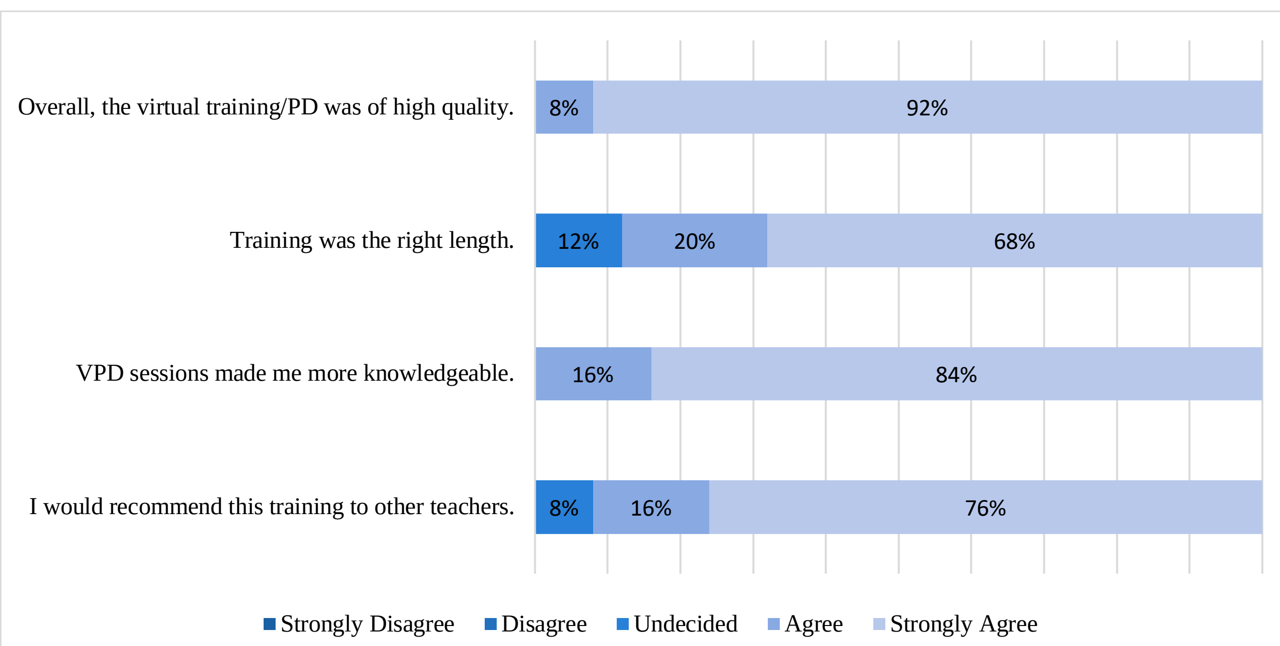
Importantly, teachers in Years 3 and 4 experienced a seismic shift in their teaching modality, due to COVID-19. Not all teachers had the same experiences with virtual instruction; because of COVID-19 restrictions and learning modifications, teachers had to adapt to hybrid classrooms (a mixture of in-person and remote learners), which made instructional delivery tumultuous and nearly unpredictable week-to-week. Not surprisingly then, a common theme from respondents was the difficulty that virtual learning presented, particularly with science instruction that promotes hands-on activities. Teachers described the stark differences between having learners participate in hands-on activities in the classroom versus demonstrating or modeling these same activities virtually for remote learners. Further, teachers struggled with basic logistics, such as having “to figure out how to scan stuff and try to get [students] to type on it and things like that.” As a result, teachers were often left on their own to adapt their instruction to virtual environments. According to a Year 4 teacher, “I'm glad I have the Nearpod because the delivery, as far as you know, presenting the lesson when the kids were at home, the Nearpod came in quite handy.” Because of the pandemic, teachers implemented LISTO in novel, innovative ways to accommodate every student, and this posed new challenges for novice and veteran teachers.

Through focus groups, individual interviews, and an online survey, teacher participants were given an opportunity to discuss their experiences with LISTO: the professional development associated with it, the curriculum, the perceived benefits for teachers and students, and the barriers to implementation. The following sections summarize those teacher responses.

Professional development and coaching. Overall, teachers responded very positively to the virtual professional development (VPD) opportunities. As in previous years, teachers in Year 3 found that the LISTO VPD either met (44%, *n* = 11) or exceeded (56%, *n* = 14) their expectations. To this effect, all teachers either agreed (88%, *n* = 22) or somewhat agreed (12%, *n* = 3) that the VPD facilitators were effective. And, like prior years, teachers felt that the VPD fostered a sense of community with others. All Year 3 teacher respondents on the VPD survey (*n* = 25) agreed that there were multiple opportunities to interact with other participants during training sessions, that they felt a relationship with other participants, and that participants were asked to play an active role in the trainings.

Teachers in Year 3 were asked to compare their virtual professional development experiences to the more traditional, face-to-face delivery of PD sessions. Generally speaking, teachers found the virtual offering to be superior in the following ways: convenience of timing and location; the ongoing connection to classroom practices; exposure to diverse perspectives; ability to review sessions; opportunities to use technology as a learner; and accessibility to resources. And, compared to Years 1 and 2, participants in Year 3 reported increased levels of agreement for each of the items shown below.

Figure 4
Teachers' perceptions of the VPD (n =25) in Year 3



Note. Values < 5.0% are not labeled.

Teachers rated the VPD on a 5-point Likert scale where 1 = strongly disagree; 2 = disagree; 3 = undecided; 4 = agree; and 5 = strongly agree. The results follow:

- Overall, the virtual training/PD was of high quality: 100% agree; 92% strongly agree
- Training was the right length: 12% undecided; 20% agree; 68% strongly agree
- VPD sessions made me more knowledgeable: 16% agree; 84% strongly agree
- I would recommend this training to other teachers: 8% undecided; 16% agree; 76% strongly agree

Year 3 teachers did have some recommendations for improving the VPD experience, but most of the comments centered on changes in grouping and organization. For instance, teachers asked for new groupings every year (potentially within the same district), more breakout sessions, offering more opportunities for face-to-face interactions with coaches, and allowing more time for discussion of strategies that work well with particularly difficult activities. Fundamentally, teachers found the VPD to be a valuable learning experience that was responsible for improving their science and literacy instruction.

Curricula materials. Teachers were asked to provide insight into the most impactful LISTO-provided and district-provided supports. By far, teachers indicated that the LISTO-provided supports were more prevalent and more useful than the district-provided support, which was hard for many teachers to identify. Common remarks from teachers included, “I don't really know what district-provided supports we have had because I think the districts just relied heavily on what LISTO that has given us,” and “Aside from [the] mining project, LISTO has provided just about everything for us.” Others pointed out that the district funded digital subscriptions and provided access to platforms like Google Classrooms, Canvas, and Nearpod, as well as offering limited professional development and trainings. However, teachers regarded LISTO-provided supports as being far more visible and helpful. For example, teachers identified the coaching sessions and virtual professional development opportunities as being impactful. Others found the Vocabulary Cards, EduSmart, and Nearpods extremely helpful. One person said, “Without a doubt, the Nearpod resources and the fillable PDF’s have been invaluable,” adding that they have been integral in ensuring that remote learners remain just as engaged as the in-person learners. In turn, teachers felt that these LISTO-provided supports and resources made planning easier, as illustrated by this response:

> *[P]lanning was a lot more easier [sic], I think, because everything was laid out for me, and I didn't have to reinvent the wheel… In the past, I used whatever I could find on the Internet. [LISTO] was very, very helpful, especially during COVID; like, I didn't have to stress about it so much. It was really nice to have all those materials given to us.*

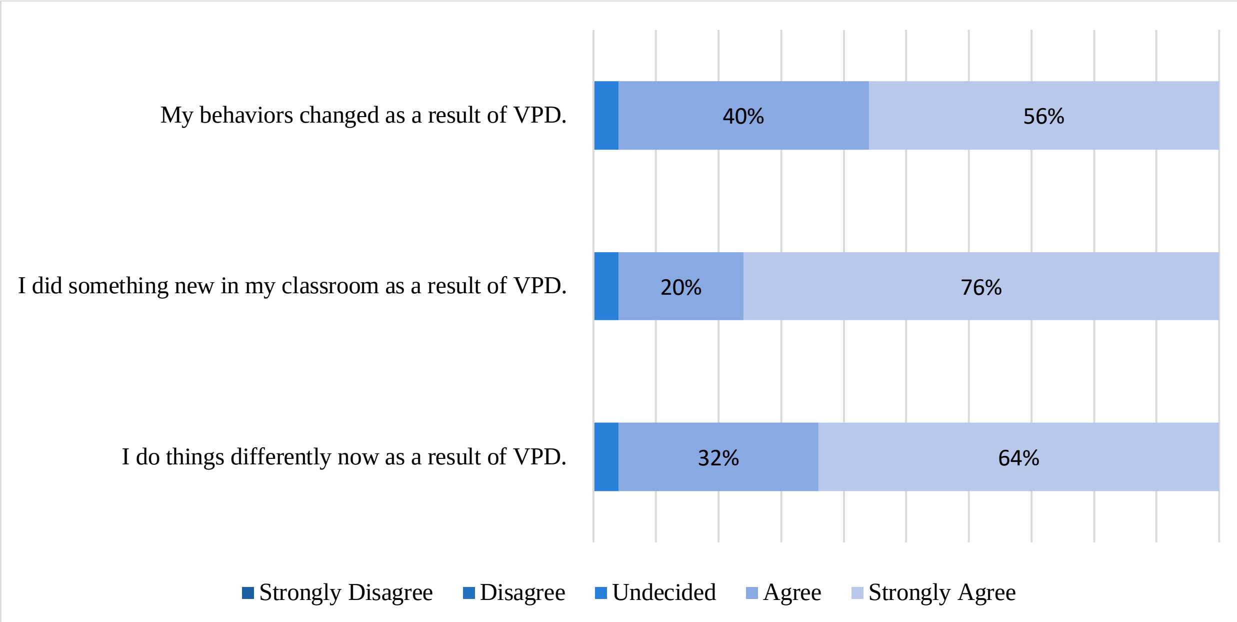
Teacher participants also were asked to compare their use of supports provided by LISTO across the duration of the project. There was broad support for an array of supports, including but not limited to, coaching and VPD, the unit planning guides and lesson plans, activity videos, FlipGrids, and LISTO-Virsity. One teacher reflected on the sustained support she received throughout the project:

> *They were very, they were all very helpful, the VPD and the Reflections. You know, when we I would meet with the coaches and stuff, they were very, very helpful. Because they were able to allow me to be able to see, like my way of teaching and what is it that I needed to [do], what is it that I needed to change, or what is it that I needed to apply more. The Reflection Cycle – that was also, you know, helpful. And the recordings. Oh my God, the recordings are that really shows you how you're, you're teaching. You're like, OK, did I just do that? So that really helped me to see teaching in a different, different perspective. And the VPD of allowing us to see ahead of time what the lessons in the activities were going to be about, those were very helpful.*

The LISTO curricula provided teachers with valuable content that helped guide learners, despite the challenges presented by the pandemic.

Perceived program benefits for teachers. There was a strong perception among teachers that LISTO benefitted them by providing them with effective instructional strategies. This is summed up with a response from a Year 3 teacher in a focus group: “I've learned strategies. My lessons are flowing. I'm able to teach them with fluency. And so [students] are getting a better lesson altogether. You know…I've learned strategies that have helped me become better, and in turn, do [a] better job.” As indicated in Figure 5 below, teachers in Year 3 primarily credited their participation in VPD with this change in their instructional practices. Almost unanimously, teachers reported that VPD had given them something new to try in the classroom and that they have changed their behavior as a direct result of the professional development.

Figure 5
Teachers’ changes in behaviors as a result of the VPD (n =25) in Year 3



Note. Values < 5.0% are not labeled.

Teachers rated the VPD on a 5-point Likert scale where 1 = strongly disagree; 2 = disagree; 3 = undecided; 4 = agree; and 5 = strongly agree. The results follow:

- My behaviors changed as a result of VPD: 4% undecided; 40% agree; 56% strongly agree
- I did something new in my classroom as a result of VPD: 4% undecided; 20% agree; 76% strongly agree
- I do things differently now as a result of VPD: 4% undecided; 32% agree; 64% strongly agree

Year 4 teachers were asked to identify literacy-infused science strategies with which they felt the most comfortable. Responses frequently mentioned the Vocabulary in Action and Reading Passages strategies. Some responses included:

> *Oh, my goodness. Vocabulary games are amazing. The kids love it. And I use that for motivation, and they look forward to it. So, I love the Vocabulary games, the reading, [and] the during reading before reading those strategies. I became very comfortable with them because I mean, I try to help the reading teacher in that way, which she absolutely loves.*

> *I mean, right off the bat, Vocabulary in Action. I mean, because that is so repetitive, because even if you have at least three of those days, you're doing Vocabulary, or you know you're doing it all the time.*

> *The Reading Passages and then the Vocabulary in Action. Because I'm teaching reading this year, it really helped make a lot of connections because they're reading passages. All the Before, During and After Reading Strategies. I've always thought the Vocabulary is*

> *very important with science. I think for whatever reason, just seeing the whole picture of how to teach reading really made a difference for me.*

In fact, Year 4 teachers reported that they have continued to use many of the LISTO-inspired strategies even after leaving the program. Again here, teachers identified the vocabulary and reading strategies as having the most longevity in their classrooms; not coincidentally, teachers also pointed to these strategies as having yielded the most return on investment for their students. As teachers noted,

> *The Vocabulary games helped them the most on the STAAR test and any type of assessments we would have. The real measure of how we were measuring success was the unit assessments that we gave, not just the STAAR test, but in their final products… Like if we had a project, and they were presenting to the class using the right Vocabulary to describe it, I really knew that they had learned something.*

> *OK, so what Literacy-infused Science Strategy has yielded the most return on investment for [my] students? I would say the reading passages and the graphic organizers. Because, again, they were able to reflect on what they just read. And it was a part of the lesson. Like if we were talking about natural disasters and the passage was on earthquakes… they get the lesson, but now they're also reading about it. They didn't just look at slides and videos. There's also reading embedded into science and they're able to show their understanding with their graphic organizer.*

LISTO benefitted teachers in a number of ways by sparking change in their instructional practices using successful vocabulary and reading-based strategies. According to a Year 3 teacher, "I feel like I've become a better teacher." This is reinforced by the largely positive views of the teachers and by the continued use of strategies by their own volition. LISTO not only impacted teachers but students as well.

Perceived program benefits for students. Overwhelmingly, teachers indicated that LISTO provided clear and valuable benefits to learning science. Year 4 teachers noticed a significant shift in learner motivation compared to previous years, when instruction was largely hands-off or conducted virtually, due to COVID-19 restrictions. Students exhibited more enthusiasm in the classroom for LISTO activities; one teacher recalled that, "They all want to be in my class…They know they're going to learn by doing." The difference between in-person and virtual learning was palpable for many teachers. A Year 4 teacher commented:

> *[W]hen they were all virtual, it was a little bit difficult for us to get them motivated because I feel like I mean, sometimes they're paying attention, sometimes they're not. So, it was a little more of a struggle to get them motivated, especially the ones that are virtual. And even to this day, I have more trouble motivating the ones that are still virtual. But because most of the time they're not completing the handouts or not for as much as I try to get them to do it. But now that they're more face to face, I think that they're more motivated since they actually get to participate and do the activities. So that makes it a lot more fun and interesting for them.*

The hands-on nature of LISTO activities were a welcomed return to in-person instruction for students who had spent the previous year at home with virtual learning where there can be numerous distractions. One teacher lamented the “big divide” between teaching science virtually and in-person, noting that some virtual students are “fallen by the wayside and rarely engage, rarely participate.” Alternatively, students who experience hands-on LISTO activities in the classroom are more connected and motivated to learn.

According to teachers, LISTO has even changed the way that students learn about science. Most predominantly, teachers pointed to the Writing Opportunities, which “makes [students] think about what they just did, how it happened, and be more detailed of what they learned from it.” More specifically, the Vocabulary in Action activities gave students the academic words to express themselves more clearly; one teacher noted that these activities helped students to speak more articulately when describing science concepts. The deliberate act of writing helped to augment comprehension and understanding, or as one teacher described: “The reading and the writing work together.” As a result, teachers feel strongly that LISTO has impacted the reading and writing abilities of their learners, especially for low-level readers.

Regarding reading, Years 3 and 4 teachers saw gains in comprehension and in confidence levels and attribute this to LISTO. One teacher stated that the literacy-based curriculum “improves their comprehension and helps them make connections in science,” and from an instructional perspective, it provides the teacher with more insight into what the learner might be struggling with. Another added that she observed demonstrable gains in reading, specifically with respect to her students’ phonics skills.

Teachers also perceived LISTO as improving their students’ writing skills. Some teachers commented that many of their students did not like to write, or even “feared it.” A Year 4 teacher explained that:

> *They feared reading in English. They feared writing. They are traumatized from writing because they just came from drill. A lot of drilling and answering perhaps from fourth grade. So, this is to them a different writing like this is to them like writing where they can actually really express themselves on their observations as opposed to, I got to answer that prompt and to them.*

A common observation was that the reading passages helped to engage learners initially with the content, and then, the writing opportunities reinforced this understanding. Others noted the increase in the number of students who wrote in complete sentences as opposed to the beginning of the year, when they were writing in abbreviated, fragmented phrases. In summary, teachers consistently reported that their students’ writing skills improved as a direct result of LISTO.

Barriers to implementation. Teachers reported fewer barriers in Years 3 and 4, compared to the previous implementation years. This likely is due to the familiarity with LISTO that students and teachers develop over time. Several teachers in Year 3 focus groups expressed this view, stating: “Every year it's better and better. I'm understanding that more. The kids are understanding it more and they enjoy it.” Another contributed by saying, “This is my third year participating in the LISTO program, and every year it just gets better and better.” Still another attributed the success of the program to repetition: “It's a constant routine that [students] are used to every day.” Several teachers commented that their confidence levels have increased over time as well. As time goes by, and experience with LISTO deepens, the barriers to implementation recede.

Recommendations for improvement. LISTO teacher participants in the focus groups were asked to provide recommendations for program improvement. The following recommendations were the most frequently cited. For the most part, these recommendations were not unpacked further, in terms of their justification or rationale. Regardless, these recurring themes provide valuable insights for program improvement:

- Create local groups for virtual professional development, when possible, and limit them to small groups (fewer than 6 people).
- Designate a social media account for LISTO and encourage teachers to join in order to share resources, ideas, and network across districts.
- Re-organize the Canvas site for easier access to and location of resources and activities.

Generally speaking, teachers gave fewer recommendations for improvement than in Years 1 and 2. Mostly, the suggestions centered on communication between other LISTO teachers, whether through virtual opportunities, social media accounts, or other networking events; teachers expressed an interest in knowing what other LISTO participants are doing and what is working the best.

Conclusion

LISTO (Valid 45), and the corresponding VPD, VMC, and curricula resources benefitted teachers and their instructional practices, despite unforeseen barriers to implementation and a subsequently shortened intervention period. While student achievement is important, it is a necessary but tangential aspect of this study, the main focus was to provide teachers with innovative, research-based strategies for instruction and to improve teacher sustainability with diminishing support. In this view, LISTO successfully facilitated the teaching experience. Specifically, LISTO had positive effects on teacher practices for a subsample of teachers, specifically on increased delivery of research-based instruction to teach science content as rated on a rubric by external reviewers. There were no differences in two other teacher outcomes, however, focused on the share of instructional time spent teaching new science content while performing various activities.

The LISTO teachers who participated in the program reported a high level of satisfaction with the VPD and VMC opportunities, and there was a strong perception among teachers that LISTO benefitted them by providing them with effective instructional strategies, specifically referencing the vocabulary and reading strategies as having the most longevity in their classrooms. At times, teachers found the VPD and VMC sessions lengthy and covered upcoming lesson units, not necessarily the unit some teachers were implementing at that time, yet the VPD allowed for greater teacher collaboration, and overall, teachers found the VPD and VMC to be very helpful and useful. The curricula were also appreciated by the teachers, with first-year teachers in particular benefitting from the pacing guides. Teachers also reported some barriers to implementation, including technological issues with the hardware and software and inadequate instructional time to fully engage with and implement the program. But for those who implemented LISTO with high fidelity, the teaching experience and the quality of instruction showed marked improvement.

However, LISTO did not necessarily lead to improved student achievement in science or reading for students in the state of Texas. There was a negative program impact on students' science achievement in each year, with the exception of Year 3, when science achievement data was not collected. These quantitative findings were in conflict with qualitative data collected from LISTO teachers who indicated that the program led to improvements in both science vocabulary and engagement and self-efficacy in science for students. Although LISTO teachers indicated that the program had benefited their struggling readers, there was no observed program impact on student reading achievement in any of the study years. While LISTO may have yielded some benefits for students, these benefits were not well captured on standardized tests or survey instruments after only one year of exposure to LIS lessons.

One potential reason for the lack of observed positive effects on student outcomes was that the teacher participation in VPD and VMC components of the program were not programmatically implemented with fidelity. Perhaps this was due to the unusually high threshold for fidelity (90% or more). For instance, there were four VMC sessions offered in Year 3 and four VPD sessions offered in Year 4, which meant that if a teacher missed one session (an attendance rate of 75%), this would not be considered as having met fidelity. Across all four years, teachers attended 90% of the VPD sessions in 25-72% of schools and 90% of the VMC sessions in 70-88% of schools, depending on the implementation year. The participation in VMC was slightly more pronounced compared to the VPD session offerings. Due to these wide-ranging fidelity scores, it may be important to note that LISTO teachers may not have participated in the program to the extent needed to observe program impacts on student and teacher outcomes.

In sum, LISTO appeared to improve instructional practices for a small sample of teachers who implemented the program but did not positively impact student outcomes more broadly. One likely reason for the lackluster effects were the issues that impacted the first year of the project, such as incomplete implementation of all proposed project components, which were exacerbated by the disruptions from the hurricane, causing a late start in many districts during the first year and delayed component implementation, followed by the complications that arose from the COVID-19 pandemic in Year 3 (2019–20). Arguably, having limited years (and here, less total program time than originally planned) to learn and implement a new curriculum reduces the capacity of teachers to perfect instructional strategies and consequently impact student achievement relative to control-group colleagues who may employ less innovative but more familiar curricula. Likewise, only one year's exposure by students to novel ways of learning science could limit the development of positive attitudes or translate increases in learning quality from LISTO to higher achievement on standardized science and reading assessments. Encouragingly, teachers' overall positive reactions to the program suggest its potential to improve student affect and learning, but more extensive implementation experience by teachers and multi-year exposure by students starting from earlier grades may be needed to yield measurable benefits. Clearly, such focuses emerge as a highly recommended topic for future research.

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Appendices

The technical appendices include required i3 tables and instruments used in the study.

Appendix A: i3 Tables

This appendix contains all tables required of evaluations funded by the Investing in Innovation (i3) Fund. Tables include:

- Master list of contrasts
- Impact tables
- Cluster attrition tables
- Baseline equivalence tables
- Fidelity of implementation tables

Master list of contrasts. Table A1 provides a master list of student contrasts, and Table A2 provides a master list of teacher contrasts. These tables also include the outcome and pretest measures, as well as the timing of the administration of the measures. Finally, these tables include whether the contrast was confirmatory (C) or exploratory (E).

Table A1

Master list of student contrasts

Contrast ID	T-Group	C-Group	Domain	Outcome Measure	Outcome Measure	Pretest Measure	Pretest Measure	C/E
T_Students_1_Y1	T in Y1	C in Y1	Science	STAAR Science	Spring 2018	ITBS Science	Fall 2017	E
T_Students_2_Y2	T in Y2	C in Y2	Science	STAAR Science	Spring 2019	ITBS Science	Fall 2017 or 2018	C
T_Students_3_Y1	T in Y1	C in Y1	Science	ITBS Science	Spring 2018	ITBS Science	Fall 2017	E
T_Students_4_Y2	T in Y2	C in Y2	Science	ITBS Science	Spring 2019	ITBS Science	Fall 2018	E
T_Students_5_Y1	T in Y1	C in Y1	Science	BISA	Spring 2018	BISA	Fall 2017	E
T_Students_6_Y2	T in Y2	C in Y2	Science	BISA	Spring 2019	BISA	Fall 2018	E
T_Students_7_Y1	T in Y1	C in Y1	Science	Science survey	Spring 2018	Science survey	Fall 2017	E
T_Students_8_Y2	T in Y2	C in Y2	Science	Science survey	Spring 2019	Science survey	Fall 2018	E
T_Students_9_Y1	T in Y1	C in Y1	Reading	STAAR Reading	Spring 2018	STAAR Reading	Spring 2017	E
T_Students_10_Y2	T in Y2	C in Y2	Reading	STAAR Reading	Spring 2019	STAAR Reading	Spring 2018	C
T_Students_11_Y4	T in Y4	C in Y4	Science	STAAR Science	Spring 2021	BISA	Fall 2020	E
T_Students_12_Y4	T in Y4	C in Y4	Science	ITBS Science	Spring 2021	ITBS Science	Fall 2020	E
T_Students_13_Y4	T in Y4	C in Y4	Science	BISA	Spring 2021	BISA	Fall 2020	E
T_Students_14_Y4	T in Y4	C in Y4	Science	Science Survey	Spring 2021	Science Survey	Fall 2020	E
T_Students_15_Y4	T in Y4	C in Y4	Reading	STAAR Reading	Spring 2021	BISA	Fall 2020	E

Notes. 1. The research design for all domains was CRT with school assignment. 2. In all cases, exposure to the treatment was one school year. 3. The unit of observation for all domains was the student. 4. The student sample included all study participants who had non-missing pretest and posttest scores. 5. The scale for all measures was continuous. 6. No Year 3 contrasts are included, as no posttests were administered during this school year, due to the COVID -19 pandemic.

Table A2
Master list of teacher contrasts

Contrast ID	T-Group	C-Group	Domain	Outcome Measure	Outcome Measure	Pretest Measure	Pretest Measure	C/E
T_Teachers_1_Y2	T in Y2	C in Y2	Science	TBOP 1	Spring 2019	TBOP 1	Fall 2017 or 2018	C
T_Teachers_2_Y2	T in Y2	C in Y2	Science	TBOP 2	Spring 2019	TBOP 2	Fall 2017 or 2018	C
T_Teachers_3_Y2	T in Y2	C in Y2	Science	STOR	Spring 2019	STOR	Fall 2017 or 2018	C
T_Teachers_4_Y3	T in Y3	C in Y3	Science	TBOP 1	Winter 2020	TBOP 1	Fall 2017, 2018, or 2019	E
T_Teachers_5_Y3	T in Y3	C in Y3	Science	TBOP 2	Winter 2020	TBOP 2	Fall 2017, 2018, or 2019	E
T_Teachers_6_Y3	T in Y3	C in Y3	Science	STOR	Winter 2020	STOR	Fall 2017, 2018, or 2019	E
T_Teachers_7_Y4	T in Y4	C in Y4	Science	TBOP 1	Spring 2021	TBOP 1	Fall 2017, 2018, or 2019	E
T_Teachers_8_Y4	T in Y4	C in Y4	Science	TBOP 2	Spring 2021	TBOP 2	Fall 2017, 2018, or 2019	E
T_Teachers_9_Y4	T in Y4	C in Y4	Science	STOR	Spring 2021	STOR	Fall 2017, 2018, or 2019	E

Notes. 1. The research design for all domains was CRT with school assignment. 2. Exposure to the treatment was either one or two school years, depending on when teachers joined the study. 3. The unit of observation for all domains was the teacher. 4. The teacher sample included all study participants who had non-missing pretest and posttest scores. 5. The scale for all measures was continuous; note that TBOP is a proportion. 6. TBOP 1 was the share of instructional time spent teaching new science content while students performed academic tasks or received feedback. TBOP 2 was the share of instructional time spent teaching new science content with an explicit focus on oral language. 7. The pretest was taken from fall 2017 whenever possible, but if data were missing for a teacher, the pretest was taken from the earliest available fall score.

Impact tables. Table A3 provides the impact estimates of LISTO on student outcomes. Table A4 provides the impact estimates for teacher outcomes. Table A5 lists the statistical models that were used to estimate program impacts. All impact estimates were estimated separately by school year.

The hierarchical linear models to estimate program effects on student outcomes included the following covariates:

- District
  - Rural status
  - District dummy indicators
- Student
  - Gender
  - Free and reduced-price meals
  - Race (e.g., Black, White, Latino, other, multi)
  - English learner status
  - Reclassified status
  - Migrant status
  - Special education
  - 504 status
  - Dummy indicator for took the Spanish version of the STAAR reading test in 4th grade
  - Baseline achievement (varies by outcome)
  - STAAR grade 4 reading score (in analyses not already including STAAR reading score as a pretest)
  - Teacher's alternative certification dummy indicator
  - Missing variable flags
- Teacher
  - Alternative teacher certification dummy indicator

For all analyses, no participants were dropped from the analytic sample due to missing values on background characteristics. For each characteristic, missing values were imputed, and a dummy indicator was created to flag participants who had missing values.

The hierarchical linear models to estimate program effects on teacher outcomes included the following covariates:

- District
  - Rural status
  - District dummy indicators
- Teacher
  - Baseline performance (varies by outcome)
  - Alternative certification dummy indicator
  - Missing variable flags

Note also that propensity score weighting was used in the teacher outcomes analyses.

Table A3

Impact estimates for student outcomes

Contrast ID	Outcome Measure	T School N	C School N	T Stu. N	C Stu. N	Unadj. T SD	Unadj. C SD	Pooled SD	Impact Est.	Impact SE	Std. Effect Size	p value
T_Students_1_Y1	STAAR Science	32	35	1188	1128	459.41	469.41	464.31	-48.15	24.50	-0.10	0.049
T_Students_2_Y2	STAAR Science	23	30	1346	1084	556.17	546.77	552.00	-72.67	35.58	-0.13	0.041
T_Students_3_Y1	ITBS Science	33	35	1112	1053	30.37	30.30	30.33	-0.90	1.56	-0.03	0.566
T_Students_4_Y2	ITBS Science	24	31	1289	1040	29.76	29.74	29.75	-2.15	1.78	-0.07	0.226
T_Students_5_Y1	BISA	33	35	1113	1061	5.57	5.58	5.57	-0.17	0.29	-0.03	0.548
T_Students_6_Y2	BISA	24	31	1300	1043	5.52	5.44	5.49	-0.34	0.41	-0.06	0.414
T_Students_7_Y1	Science survey	33	35	1108	1064	0.56	0.51	0.54	-0.07	0.03	-0.14	0.012
T_Students_8_Y2	Science survey	24	31	1272	1037	0.37	0.34	0.35	-0.02	0.02	-0.06	0.285
T_Students_9_Y1	STAAR Reading	32	35	1181	1160	128.22	130.56	129.39	2.65	5.01	0.02	0.597
T_Students_10_Y2	STAAR Reading	22	29	1293	993	132.56	128.98	131.02	4.09	5.73	0.03	0.476
T_Students_11_Y4	STAAR Science	12	11	392	165	466.75	526.24	485.09	52.74	121.32	0.11	0.664
T_Students_12_Y4	ITBS Science	3	6	143	167	33.97	30.22	32.00	-6.30	9.41	-0.20	0.503
T_Students_13_Y4	BISA	13	13	385	254	6.77	5.83	6.41	0.11	1.10	0.02	0.922
T_Students_14_Y4	Science survey	13	14	378	257	0.75	0.64	0.71	-0.10	0.11	-0.14	0.360
T_Students_15_Y4	STAAR Reading	12	11	394	166	156.03	140.52	151.61	-0.82	38.92	-0.01	0.983

Note. The degrees of freedom for all models were infinity.

Table A4

Impact estimates for teacher outcomes

Contrast ID	**Outcome Measure**	**T School *N***	**C School *N***	**T Teach. *N***	**C Teach. *N***	**Unadj. T SD**	**Unadj. C SD**	**Pooled SD**	**Impact Est.**	**Impact SE**	**Std. Effect Size**	**p value**
T_Teachers_1_Y2	TBOP 1	19	25	33	38	0.10	0.14	0.12	-0.02	0.04	-0.20	0.5488
T_Teachers_2_Y2	TBOP 2	19	25	33	38	0.13	0.22	0.18	-0.05	0.07	-0.27	0.4686
T_Teachers_3_Y2	STOR	6	17	8	22	0.34	0.43	0.41	0.45	0.18	1.12	0.0118
T_Teachers_4_Y3	TBOP 1	13	20	29	32	0.14	0.13	0.13	0.03	0.04	0.19	0.485
T_Teachers_5_Y3	TBOP 2	13	20	29	32	0.16	0.21	0.19	0.03	0.05	0.14	0.602
T_Teachers_6_Y3	STOR	13	20	26	32	0.39	0.41	0.40	0.60	0.12	1.49	<.001
T_Teachers_7_Y4	TBOP 1	10	13	15	17	0.19	0.15	0.17	0.09	0.07	0.52	0.177
T_Teachers_8_Y4	TBOP 2	10	13	15	17	0.19	0.09	0.14	-0.00	0.06	-0.01	0.981
T_Teachers_9_Y4	STOR	13	13	23	18	0.36	0.28	0.33	0.41	0.11	1.24	<.001

Notes. 1. All Y2 measures, along with Y3 and Y4 STOR, failed baseline equivalence and were adjusted using propensity score weighting. 2. The degrees of freedom for all models were infinity.

Table A5

Statistical models used to estimate program impacts on student and teacher outcomes

Contrast ID	Outcome Measure	Model
T_Students_1_Y1	STAAR Science	mixed staar_science_post treat grand_* if year1==1 & !missing(staar_science_post) & !missing(itbs_pre) || schid: ,
T_Students_2_Y2	STAAR Science	mixed staar_science_post treat grand_* if year2==1 & !missing(staar_science_post) & !missing(itbs_pre) || schid: ,
T_Students_3_Y1	ITBS Science	mixed itbs_post treat grand_* if year1==1 & !missing(itbs_post) & !missing(itbs_pre) || schid: ,
T_Students_4_Y2	ITBS Science	mixed itbs_post treat grand_* if year2==1 & !missing(itbs_post) & !missing(itbs_pre) || schid: ,
T_Students_5_Y1	BISA	mixed bisa_post treat grand_* if year1==1 & !missing(bisa_post) & !missing(bisa_pre) || schid: ,
T_Students_6_Y2	BISA	mixed bisa_post treat grand_* if year2==1 & !missing(bisa_post) & !missing(bisa_pre) || schid: ,
T_Students_7_Y1	Science survey	mixed sciencesurvey_post treat grand_* if year1==1 & !missing(sciencesurvey_post) & !missing(sciencesurvey_pre) || schid: ,
T_Students_8_Y2	Science survey	mixed sciencesurvey_post treat grand_* if year2==1 & !missing(sciencesurvey_post) & !missing(sciencesurvey_pre) || schid: ,
T_Students_9_Y1	STAAR Reading	mixed staar_read_post treat grand_* if year1==1 & !missing(staar_read_post) & !missing(staar_read_pre) || schid: ,
T_Students_10_Y2	STAAR Reading	mixed staar_read_post treat grand_* if year2==1 & !missing(staar_read_post) & !missing(staar_read_pre) || schid: ,
T_Students_11_Y4	STAAR Science	mixed staar_sci treat grand_* if !missing(staar_sci) & !missing(bisa_pre) || schoolid : ,
T_Students_12_Y4	ITBS Science	mixed itbs_post treat grand_* if !missing(itbs_post) & !missing(itbs_pre) || schid: ,
T_Students_13_Y4	BISA	mixed bisa_post treat grand_* if !missing(bisa_post) & !missing(bisa_pre) || schid: ,
T_Students_14_Y4	Science survey	mixed sciencesurvey_post treat grand_* if !missing(sciencesurvey_post) & !missing(sciencesurvey_pre) || schid: ,
T_Students_15_Y4	STAAR Reading	mixed staar_read treat grand_* if !missing(staar_read) & !missing(bisa_pre) || schoolid : ,
T_Teachers_1_Y2	TBOP 1	mixed round3_actstruct10_1819 treat grand_* if !missing(round3_actstruct10_1819) & !missing(round1_actstruct10_pre) [pweight=ps_actstruct10_y2] || schid: ,
T_Teachers_2_Y2	TBOP 2	mixed round3_mode15_1819 treat grand_* if !missing(round3_ mode15_1819) & !missing(round1_ mode15_pre) [pweight=ps_ mode15_y2] || schid: ,
T_Teachers_3_Y2	STOR	mixed round3_stor_1819 treat grand_* if !missing(round3_ stor_1819) & !missing(round1_ stor_pre) [pweight=ps_ stor_y2] || schid: ,

Contrast ID	Outcome Measure	Model
T_Teachers_4_Y3	TBOP 1	mixed round3_actstruct10_1819 treat grand_* if !missing(round3_actstruct10_1819) & !missing(round1_actstruct10_pre) [pweight=ps_actstruct10_y2] || schid: ,
T_Teachers_5_Y3	TBOP 2	mixed round3_mode15_1819 treat grand_* if !missing(round3_ mode15_1819) & !missing(round1_ mode15_pre) [pweight=ps_ mode15_y2] || schid: ,
T_Teachers_6_Y3	STOR	mixed round3_stor_1819 treat grand_* if !missing(round3_ stor_1819) & !missing(round1_ stor_pre) [pweight=ps_ stor_y2] || schid: ,
T_Teachers_7_Y4	TBOP 1	mixed round3_actstruct10_1819 treat grand_* if !missing(round3_actstruct10_1819) & !missing(round1_actstruct10_pre) [pweight=ps_actstruct10_y2] || schid: ,
T_Teachers_8_Y4	TBOP 2	mixed round3_mode15_1819 treat grand_* if !missing(round3_ mode15_1819) & !missing(round1_ mode15_pre) [pweight=ps_ mode15_y2] || schid: ,
T_Teachers_9_Y4	STOR	mixed round3_stor_1819 treat grand_* if !missing(round3_ stor_1819) & !missing(round1_ stor_pre) [pweight=ps_ stor_y2] || schid: ,

Notes. 1. Stata version 16.1 was used to estimate all models. 2. Grand_* indicates that all covariates (e.g., the pretest, student covariates, teacher alternative certification, and district dummy variables) were included in the model, and all were grand-mean centered. 3. Note that propensity score weighting was used to estimate the models on all teacher outcomes in Year 2, as well as TBOP.

Cluster attrition tables. The following tables provide the cluster (school) attrition rates. Table A6 provides the cluster attrition for the student analyses. The cluster attrition rates (overall and differential) for all outcomes were acceptable for Year 1 student outcomes according to the WWC (2020) standards, but cluster attrition standards were not met for Year 2 or 4 student outcomes. In Year 2, two districts and three schools attrited from the study prior to program implementation due to changes in district administration. District data was not collected for another two schools that participated in 2017–18. Another nine schools attrited before the end of the 2018–19 school year. Many more schools attrited before the beginning of the 2020–21 school year, likely due in large part due to disruptions due to the COVID-19 pandemic.

Table A7 provides the cluster attrition for the teacher outcomes analyses. Cluster attrition standards were not met for any of the teacher outcomes (WWC, 2020). Because collecting the teacher outcomes required teachers to self-video a lesson and submit the video to the project team, cluster attrition was higher for the teacher outcomes than for the student outcomes.

Table A6

Cluster attrition for student outcomes

Contrast ID	Outcome Measure	T School N	C School N	N School Randomized to T	N School Randomized to C	Attrited T School	Attrited C School	Overall Sch. Attrition Rate (%)	Diff. Sch. Attrition Rate (%)
T_Students_1_Y1	STAAR Science	32	35	35	36	3	1	5.63	5.79
T_Students_2_Y2	STAAR Science	23	30	35	36	12	6	25.35	17.62
T_Students_3_Y1	ITBS Science	33	35	35	36	2	1	4.23	2.94
T_Students_4_Y2	ITBS Science	24	31	35	36	11	5	22.54	17.54
T_Students_5_Y1	BISA	33	35	35	36	2	1	4.23	2.94
T_Students_6_Y2	BISA	24	31	35	36	11	5	22.54	17.54
T_Students_7_Y1	Science survey	33	35	35	36	2	1	4.23	2.94
T_Students_8_Y2	Science survey	24	31	35	36	11	5	22.54	17.54
T_Students_9_Y1	STAAR Reading	32	35	35	36	3	1	5.63	5.79
T_Students_10_Y2	STAAR Reading	22	29	35	36	13	7	28.17	17.70
T_Students_11_Y4	STAAR Science	12	11	35	36	23	25	67.61	3.73
T_Students_12_Y4	ITBS Science	3	6	35	36	32	30	87.32	8.10
T_Students_13_Y4	BISA	13	13	35	36	22	23	63.38	1.03
T_Students_14_Y4	Science survey	13	14	35	36	22	22	61.97	1.75
T_Students_15_Y4	STAAR Reading	12	11	35	36	23	25	67.61	3.73

Table A7

Cluster attrition for teacher outcomes

Contrast ID	Outcome Measure	T School N	C School N	N School Randomized to T	N School Randomized to C	Attrited T School	Attrited C School	Overall Sch. Attrition Rate (%)	Diff. Sch. Attrition Rate (%)
T_Teachers_1_Y2	TBOP 1	19	25	35	36	16	11	38.03	15.16
T_Teachers_2_Y2	TBOP 2	19	25	35	36	16	11	38.03	15.16
T_Teachers_3_Y2	STOR	6	17	35	36	29	19	67.61	30.08
T_Teachers_4_Y3	TBOP 1	13	20	35	36	22	16	53.52	18.41
T_Teachers_5_Y3	TBOP 2	13	20	35	36	22	16	53.52	18.41
T_Teachers_6_Y3	STOR	13	20	35	36	22	16	53.52	18.41
T_Teachers_7_Y4	TBOP 1	10	13	35	36	25	23	67.61	7.54
T_Teachers_8_Y4	TBOP 2	10	13	35	36	25	23	67.61	7.54
T_Teachers_9_Y4	STOR	13	13	35	36	22	23	63.38	1.03

Baseline equivalence tables. For all analytic samples, baseline equivalence on pretests was assessed using the same analytic model to estimate program impacts, except without the covariates. In other words, the baseline mean difference was estimated using an HLM model with the pretest as the dependent variable and the treatment indicator as the independent variable. Table A8 shows the baseline equivalence for the student outcomes, and Table A9 shows the baseline equivalence for the teacher outcomes.

Baseline equivalence was initially not established for teacher outcomes. Therefore, for teacher outcomes, propensity score weighting was applied to the models used to estimate the baseline mean difference (as well as the models used to estimate impacts); consequently, all baseline differences between treatment and comparison groups were < 0.25 standard deviations. Note that all statistical models estimating program effects included the pretest as a covariate.

Table A8

Baseline equivalence for student outcomes

Contrast ID	**Pretest Measure**	**T Student N**	**C Student N**	**Unadj T SD at Pretest**	**Unadj C SD at Pretest**	**Pooled SD for T and C**	**C Mean at Pretest**	**T/C Diff. at Pretest**	**Std. T/C Diff. at Pretest**
T_Students_1_Y1	ITBS Science	1188	1128	24.85	25.05	24.95	197.94	-4.16	-0.17
T_Students_2_Y2	ITBS Science	1346	1084	23.90	26.04	24.88	195.82	-4.57	-0.18
T_Students_3_Y1	ITBS Science	1112	1053	24.74	25.02	24.87	198.66	-4.69	-0.19
T_Students_4_Y2	ITBS Science	1289	1040	24.12	25.45	24.72	194.95	-3.75	-0.15
T_Students_5_Y1	BISA	1113	1061	5.24	5.15	5.20	14.57	-0.68	-0.13
T_Students_6_Y2	BISA	1300	1043	5.20	5.32	5.25	14.62	-0.62	-0.12
T_Students_7_Y1	Science survey	1108	1064	0.52	0.48	0.50	3.29	0.01	0.01
T_Students_8_Y2	Science survey	1272	1037	0.37	0.35	0.36	3.15	0.03	0.09
T_Students_9_Y1	STAAR Reading	1181	1160	131.74	140.69	136.25	1492.08	-14.19	-0.10
T_Students_10_Y2	STAAR Reading	1293	993	130.33	131.73	130.94	1502.75	-13.48	-0.10
T_Students_11_Y4	BISA	392	165	4.24	4.27	392	10.39	1.11	0.26
T_Students_12_Y4	ITBS Science	143	167	26.91	28.16	143	196.07	-13.12	-0.48
T_Students_13_Y4	BISA	385	254	4.27	4.41	385	10.74	0.66	0.15
T_Students_14_Y4	Science survey	378	257	0.45	0.42	378	3.66	0.18	0.41
T_Students_15_Y4	BISA	394	166	4.24	4.26	4.25	10.37	1.13	0.27

Notes. 1. The source for the standard deviations was the sample. 2. The outcome measure was the same as pretest measure for all domains except when the outcome was STAAR science. The pretest for STAAR Science was ITBS science in Year 2. In Year 4, the pretest for STAAR in both subjects was BISA.

Table A9

Baseline equivalence for teacher outcomes

Contrast ID	Pretest Measure	T Teacher N	C Teacher N	Unadj T SD at Pretest	Unadj C SD at Pretest	Pooled SD for T and C	C Mean at Pretest	T/C Diff. at Pretest	Std. T/C Diff. at Pretest
T_Teachers_1_Y2	TBOP 1	33	38	0.15	0.15	0.15	0.12	0.00	0.00
T_Teachers_2_Y2	TBOP 2	33	38	0.18	0.25	0.22	0.27	0.00	0.02
T_Teachers_3_Y2	STOR	8	22	0.19	0.26	0.25	2.19	0.00	0.01
T_Teachers_4_Y3	TBOP 1	29	32	0.16	0.12	0.14	0.11	0.03	0.20
T_Teachers_5_Y3	TBOP 2	29	32	0.21	0.24	0.22	0.27	-0.04	-0.18
T_Teachers_6_Y3	STOR	26	32	0.60	0.56	0.58	3.02	0.02	0.04
T_Teachers_7_Y4	TBOP 1	15	17	0.22	0.15	0.18	0.10	0.00	0.02
T_Teachers_8_Y4	TBOP 2	15	17	0.18	0.15	0.16	0.16	0.04	0.24
T_Teachers_9_Y4	STOR	23	18	0.41	0.46	0.43	2.82	0.10	0.23

Notes. 1. The source for the standard deviations was the sample. 2. The outcome measure was the same as pretest measure. 3. All Year 2 measures, along with Year 3 and Year 4 STOR, initially failed baseline equivalence and were adjusted using propensity score weighting.

Fidelity of implementation. Table 8 in the report shows that key components of LISTO were not implemented with fidelity. Table A10 shows the fidelity of implementation for each of the key program components by school year. LISTO included three major program components: virtual professional development (VPD), virtual mentoring and coaching (VMC), and literacy-infused science curricula (LIS). Fidelity of VPD, VMC, and curricular materials were each measured at teacher, school, and component levels (see Table 4). High fidelity for each program component was defined at the sample level and if 90% of participating schools had high fidelity, as outlined in Table 4.

Table A10

Fidelity of implementation of each key program component by school year

Key Component 1 (of 3) – Virtual Professional Development (VPD). Fidelity Matrix and Fidelity Results Reporting Table

Indicators	**Definition**	**Unit of implementation**	**Data Source(s)**	**Data Collection (who, when)**	**Score for levels of implementation at unit level**	**Threshold for adequate implementation at unit level**	**Roll-up to next higher level if needed (score and threshold): Indicate level**		**Roll-up to sample level (score and threshold for adequate implementation at sample level)**	**Expected sample for fidelity measure (n = # units in which the intervention is being implemented)**	**Expected years of fidelity measurement**
VPD for teachers	# of PD sessions attended by teacher	Teacher	VPD-Use Survey GoToTraining reports	Collected by TAMU Annually in spring of Years 1 & 2	% of PD sessions attended by teacher	Adequate =1 1 = Teacher participates in at least 90% of PD sessions 0= Teacher participates in < 90% of PD sessions	Adequate = 1 1 = 100% of teachers in a school have score of 1. 0 = <100% of teachers in a school have score of 1		Adequate = 1 1= at least 90% of schools have a score of 1. 0 < 90% of schools have a score of 1	All treated 5th grade science teachers in all treatment schools (Y1, n = 44 teachers; Y2, n = 33 teachers)	2017-18 (Year 1) 2018-19 (Year 2) 2019-20 (Year 3) 2020-21 (Year 4)

VPD for teachers	# of teachers that completed VPD	School	VPD-Use Survey GoToTraining reports	Collected by TAMU Annually in spring of Years 1 & 2	% of teachers that completed VPD	Adequate =1 1 = 100% of participating teachers have high fidelity 0 = Less than 100% of participating teachers have high fidelity	Adequate = 1 1 = 100% of teachers in a school have score of 1. 0 = <100% of teachers in a school have score of 1	.	Adequate = 1 1= at least 90% of schools have a score of 1. 0 < 90% of schools have a score of 1	All treated schools with teacher participants (Year 1, n = 32 schools; Y2, n = 26 schools)	2017-18 (Year 1) 2018-19 (Year 2) (Year 3) 2020-21 (Year 4)
Key component score							Adequate if: 90% of schools have a sum score of 2				

Fidelity Results		**Threshold**	90% of schools have a sum score of 2	**# of Units Measured (of n=35 schools)**	**Year of Measurement**
		Achieved Score at the Sample Level	**80% of teachers** **72% of schools**	**44 teachers** **32 schools**	**2017-18**
		Met Threshold Implemented with Fidelity (Yes, No, N/A)	**No**		
		Achieved Score at the Sample Level	**77% of teachers** **62% of schools**	**33 teachers** **26 schools**	**2018-19**
		Met Threshold Implemented with Fidelity (Yes, No, N/A)	**No**		
		Achieved Score at the Sample Level	**69% of teachers** **69% of schools**	**35 teachers** **16 schools**	**2019-20**

	Met Threshold Implemented with Fidelity (Yes, No, N/A)	**No**		
	Achieved Score at the Sample Level	**56% of teachers** **25% of schools**	**38 teachers 16 schools**	**2020-21**
	Met Threshold Implemented with Fidelity (Yes, No, N/A)	**No**		

Key Component 2 (of 3) – Virtual Mentoring and Coaching (VMC). Fidelity Matrix and Fidelity Results Reporting Table

Indicators	**Definition**	**Unit of imple-mentation**	**Data Source(s)**	**Data Collection (who, when)**	**Score for levels of implementa-tion at unit level**	**Threshold for adequate implementation at unit level**	**Roll-up to next higher level if needed (score and threshold): Indicate level**		**Roll-up to sample level (score and threshold for adequate implementation at sample level)**	**Expected sample for fidelity measure (n = # units in which the intervention is being implemented)**	**Expected years of fidelity measurement**
VMC for teachers	# of coaching sessions attended by teacher	Teacher	VMC-Use Survey GoToTraining reports	Collected by TAMU Annually in spring of Years 1 & 2	% of coaching sessions attended by teacher	Adequate =1 1 = Teacher participates in at least 90% of coaching sessions 0= Teacher participates in < 90% of coaching sessions	Adequate = 1 1 = 100% of teachers in a school have score of 1. 0 = <100% of teachers in a school have score of 1	.	Adequate = 1 1= at least 90% of schools have a score of 1. 0 < 90% of schools have a score of 1	All treated 5th grade science teachers in all treatment schools (n=35)	2017-18 (Year 1) 2018-19 (Year 2) (Year 3) 2020-21 (Year 4)
VMC for teachers	# of teachers that completed VMC	School	VMC-Use Survey GoToTraining reports	Collected by TAMU Annually in spring	% of teachers that completed VMC	Adequate =1 1 = 100% of participating teachers have high fidelity	Adequate = 1 1 = 100% of teachers in a school have score of 1. 0 = <100% of teachers in		Adequate = 1 1= at least 90% of schools have a score of 1.	All treated 5th grade science teachers in all treatmen	2017-18 (Year 1) 2018-19 (Year 2) (Year 3) 2020-21 (Year 4)

				of Years 1 & 2		0 = Less than 100% of participating teachers have high fidelity	a school have score of 1	0 < 90% of schools have a score of 1	t schools (n=35)	
Key component score							Adequate if: 90% of schools have a sum score of 2			

Fidelity Results		**Threshold**	90% of schools have a sum score of 2	**# of Units Measured (of n= 35 schools)**	**Year of Measurement**
		Achieved Score at the Sample Level	**74% of teachers** **73% of schools**	**42 teachers** **33 schools**	**2017-18**
		Met Threshold Implemented with Fidelity (Yes, No, N/A)	**No**		
		Achieved Score at the Sample Level	**70% of teachers** **54% of schools**	**30 teachers** **24 schools**	**2018-19**
		Met Threshold Implemented with Fidelity (Yes, No, N/A)	**No**		
		Achieved Score at the Sample Level	**88% of teachers** **69% of schools**	**32 teachers** **16 schools**	**2019-20**
		Met Threshold Implemented with Fidelity (Yes, No, N/A)	**No**		
		Achieved Score at the Sample Level	**86% of teachers** **47% of schools**	**28 teachers** **15 schools**	**2020-21**
		Met Threshold Implemented with Fidelity (Yes, No, N/A)	**No**		

Key Component 3 (of 3) – LISTO curriculum. Fidelity Matrix and Fidelity Results Reporting Table

Indicators	**Definition**	**Unit of imple-mentation**	**Data Source(s)**	**Data Collection (who, when)**	**Score for levels of implementa-tion at unit level**	**Threshold for adequate implementa-tion at unit level**	**Roll-up to next higher level if needed (score and threshold): Indicate level**	**Roll-up to sample level (score and threshold for adequate implementation at sample level)**	**Expected sample for fidelity measure (n = # units in which the intervention is being implemented)**	**Expected years of fidelity measurement**
LISTO curriculum	Teacher receives curriculum	Teacher	VPD-Use Survey GoToTraining reports	Collected by TAMU Annually in spring of Years 1 & 2	1 = teacher receives curriculum 0=teacher does not receive curriculum	Adequate =1 1 = Teacher receives curriculum 0= teacher does not receive curriculum	Adequate = 1 1 = 100% of teachers in a school have score of 1. 0 = <100% of teachers in a school have score of 1	Adequate = 1 1= at least 90% of schools have a score of 1. 0 < 90% of schools have a score of 1	All treated 5th grade science teachers (approx. 70) in all treatment schools (35)	2017-18 (Year 1) 2018-19 (Year 2) (Year 3) 2020-21 (Year 4)
Key component score							Adequate if at least 90% of schools have adequate implementation			

		Threshold	At least 90% of schools have adequate implementation	**# of Units Measured (of n=35 schools)**	**Year of Measurement**
Fidelity Results		Achieved Score at the Sample Level	**100% of schools**	**YY schools**	**2017-18**
		Met Threshold Implemented with Fidelity (Yes, No, N/A)	**Yes**		
		Achieved Score at the Sample Level	**100% of schools**	**YY schools**	**2018-19**
		Met Threshold Implemented with Fidelity (Yes, No, N/A)	**Yes**		
		Achieved Score at the Sample Level	**100% of schools**	**YY schools**	**2019-20**
		Met Threshold Implemented with Fidelity (Yes, No, N/A)	**Yes**		

	Achieved Score at the Sample Level	**100% of schools**	**YY schools**	**2020-21**
	Met Threshold Implemented with Fidelity (Yes, No, N/A)	**Yes**		

Appendix B: Science Teacher Observation Record

Science Teacher Observation Record

1. **Pacing.** Does the teacher maintain pacing within the lesson?

5. Rate of instructional delivery "right speed for students", all transitions smooth/efficient, all students paying attention

4. Rate of instructional delivery "right speed for students", most transitions smooth/efficient, most students paying attention

3. Rate of instructional delivery slightly slow or fast for students, some transitions smooth/efficient, the majority of students paying attention

2. Rate of instructional delivery slightly slow or fast for students, few transitions smooth/efficient, the majority of students not paying attention

1. Rate of instructional delivery too slow/fast, all transitions inefficient, students not paying attention

2. **Instructional presentation tools.** Does the teacher use variety of instructional presentation tools (e.g., graphs, models, visuals, hands-on science materials, power point, simulations, digital curriculum resources, online apps, internet research)?

5. Teacher uses five or more instructional presentation tools.

4. Teacher uses four instructional presentation tools.

3. Teacher uses three instructional presentation tools.

2. Teacher uses two instructional presentation tools.

1. Teacher uses one instructional presentation tool.

3. **Explanation of academic tasks and clear directions**. Does the teacher provide clear explanations/directions for academic tasks?

5. Teacher provides clear explanations/directions for all academic tasks

4. Teacher provides clear explanations/directions for majority academic tasks

3. Teacher provides clear explanations/directions for some academic tasks

2. Teacher provides clear explanations/directions for a few academic tasks

1. Teacher does not provide clear explanations/directions for any academic tasks

4. **Material Preparation**. Does the teacher prepare materials needed for instruction/demos/investigations? 5. Teacher has all materials prepared (easily accessible, organized, ready to implement).

4. Teacher has majority materials prepared (easily accessible, organized, ready to implement).

3. Teacher has some materials prepared (easily accessible, organized, ready to implement)

2. Teacher has a few materials prepared (easily accessible, organized, ready to implement)

1. Teacher does not have any materials prepared.

5. **Teacher Preparation**. Is the teacher familiar with the lesson activities and does s/he present the lesson with confidence?

5. Familiar with all the lesson activities

4. Familiar with most lesson activities

3. Familiar with some lesson activities

2. Unfamiliar with most lesson activities

1. Not familiar with any lesson activities

Factor 2: Literacy-Infusion in Science

6. **Speaking in Science**. Does the teacher provide opportunities for students to develop academic oral language in science?

For example: sentence starters, cloze sentences, discussion prompts, "put into your own words", provide support to respond in complete sentences, supportive environment for students feeling comfortable to practice oral language (e.g., gentle correction, teacher modeling accurate language usage), practicing academic language with peers, visual scaffolding (using images, graphics organizers) to support student to generate/organizing oral expression

5. Teacher provides 4 or more opportunities for students to verbally share science ideas, thoughts, responses with teacher or classmates.

4. Teacher provides 3 opportunities for students to verbally share science ideas, thoughts, responses with teacher or classmates.

3. Teacher provides 2 opportunities for students to verbally share ideas, thoughts, responses with teacher or classmates.

3. Teacher provides 1 opportunity for students to verbally share ideas, thoughts, responses with teacher or classmates.

1. Teacher does not provide opportunities for students to verbally share ideas, thoughts, responses with teachers or classmates.

7. **Reading in Science.** Does the teacher provide opportunities for students to engage in science academic reading and provide reading supports?

Pre-reading: pronouncing syllables/words, previewing vocabulary, previewing text features (headings subheadings, images, photos), predicting what text will be about, introducing reading guide

During reading: partner reading, support with tricky words, partner discussion on comprehension questions, teacher read aloud

After reading: review comprehension questions, referencing reading guide, building/referring to graphic organizer, asking students to provide text evidence, re-reading passage for clarification, reviewing text features - calling attention to captions, graphs, and relationship to topic.)

5. Teacher provides opportunity for students to read science academic text with 4 or more reading supports

4. Teacher provides opportunity for students to read science academic text with 3 reading supports

3. Teacher provides opportunity for students to read science academic text with 2 reading supports

2. Teacher provides opportunity for students to read science academic text with 1 reading supports

1. Teacher does not provide opportunity for students to read science academic text

8. **Writing in Science.** Does the teacher provide opportunities for students to engage in student-generated science academic writing? For example (journal entries, observations, notes, reflections, charts/graphs, drawing and labeling images, responses, paragraphs, CER - claims, evidence, reasoning).

5. Teacher provides 4 or more opportunities for students to write student-generated science text.4. Teacher provides 3 opportunities for students to write student-generated science text.

3. Teacher provides 2 opportunities for students to write student-generated science text.

2. Teacher provides 1 opportunity for students to write student-generated science text.

1. Teacher does not provide opportunity for students to write student-generated science text.

9. **Language Objectives**. Does teacher clearly define language objectives in science lesson and are the language objectives supported by lesson delivery? Language objectives are (a) clearly defined/introduced, (b) reviewed with students/referred to the objectives during lesson delivery.

5. Language objectives are clearly defined/introduced and referred to/reviewed during more than 1 lesson activity.

4. Language objectives are clearly defined/introduced and referred to/reviewed during1 lesson activity.

3. Language objectives are clearly defined/introduced, but not referred to/reviewed during lesson.

2. Language objectives are implied.

1. Language objectives are not included.

10. **Academic Language Development in Science**. Does the teacher explicitly teach science vocabulary using a variety of academic language scaffolding strategies?

For example: vocabulary word wall cards, vocabulary power point slide, part of speech, use of real color images, student friendly definition, opportunities for students to practice using vocabulary, drawing an image to represent vocabulary, Frayer model, making connections to vocabulary, discussing multiple-meaning words, vocabulary games, student vocabulary cards, use of student glossary.

5. Teacher employs 4 or more academic language scaffolding strategies to develop science vocabulary.

4. Teacher employs 3 academic language scaffolding strategies to develop science vocabulary.

3. Teacher employs 2 academic language scaffolding strategies to develop science vocabulary.

2. Teacher employs 1 academic language scaffolding strategy to develop science vocabulary.

1. Teacher does not employ academic language scaffolding strategies.

Factor 3: Science Concept Development

11. **Making Connections to Previous Knowledge**. Does the teacher provide opportunities for students to make connections between their previous existing knowledge to new science concepts? For example: accessing what students already know, asking about related experiences, warm-up activity, questions or discussion “this reminds me of…” “I remember when...” “I saw this at…”, asking what student knows about topic, vocabulary word before providing content, reviewing previous activity and making connections to new activity (can be found in engage, explore, explain, elaborate, evaluate).

5. Teacher provides 4 or more opportunities for students to make connections between previous knowledge to new science concepts.

4. Teacher provides 3 opportunities for students to make connections between previous knowledge to new science concepts.

3. Teacher provides 2 opportunities for students to make connections between previous knowledge to new science concepts.

2. Teacher provides 1 opportunity for students to make connections between previous knowledge to new science concepts.

1. Teacher does not provide opportunity for students to make connections between previous knowledge to new science concepts.

12. **Making Connections to Real World**. Does the teacher provide opportunities for students to make connections between science content and real world?

For example: make connections between science concept and related careers, set context or scenario related to real-world issues, include guest speaker/scientist in-person or virtual, ask reflection questions related to real-world application ‘I think this concept is important to my community because ___.”, make connections to news, simulate real-world experience, ‘publish’ student work for the community.

5. Teacher provides 4 or more opportunities for students to make connections between science content and real world.

4. Teacher provides 3 opportunities for students to make connections between science content and real world.

3. Teacher provides 2 opportunities for students to make connections between science content and real world.

2. Teacher provides 1 opportunity for students to make connections between science content and real world.

1. Teacher does not provide opportunity for students to make connections between science content and real world.

13. **Cognitive Feedback in Science**. Does the teacher provide timely cognitive feedback (address student alternative conceptions, incorrect responses, scaffold explain where and why an error was made, opportunity for student to improve/get right when needed with additional student response, elaboration, or demonstration) and specific content praise (provide praise linked to cognitive task for example Great job comparing living and nonliving)?

5. Consistently provides timely cognitive feedback with opportunities for students to improve/get right when needed (regular, uniform, naturally flowing) AND provides specific content praise

4. Consistently provides timely cognitive feedback with opportunities for students to improve/get right when needed (regular, uniform, naturally flowing) but does NOT provide specific content praise.

3. Sometimes provides timely cognitive feedback with opportunities for students to improve/get right when needed (inconsistent, irregular, unequal, not naturally flowing) AND provides specific content feedback.

2. Sometimes provides timely cognitive feedback with opportunities for students to improve/get right when needed (inconsistent, irregular, unequal, not naturally flowing), but does NOT provide specific content feedback.

1. Does not provide timely cognitive feedback

14. **Science Objectives.** Does teacher clearly define science objectives and are the science objectives supported by lesson delivery? Science objectives are (a) clearly defined/introduced, (b) reviewed with students/referred to the objectives during lesson delivery.

5. Science objectives are clearly defined/introduced and referred to/reviewed during more than 1 lesson activity.

4. Science objectives are clearly defined/introduced and referred to/reviewed during 1 lesson activity.

3. Science objectives are clearly defined/introduced, but not referred to/reviewed during lesson.

2. Science objectives are implied.

1. Science objectives are not included.

15. **Science Leveled Questioning**. Does teacher ask leveled questions that probe for higher order cognitive processes?

5. Highest level of teacher questioning is level 5 or above (create, design, invent, plan, predict, revise, suggest, defend, evaluate, provide evidence, evaluate, justify, prioritize).

4. Highest level of teacher questioning is level 4 (analyze, classify, compare, contrast, diagram, provide evidence)

3. Highest level of teacher questioning is level 3 (apply, conclude, demonstrate, give an example, show, solve).

2. Highest level of teacher questioning is level 2 (describe, explain, paraphrase, put in own words, summarize)

1. Level 1 questions only (define, list, identify, label, name, recall, underline).

16. **Formative Assessment**. Does teacher utilize formative assessments to monitor student learning/understanding of science concepts and make instructional adjustments (review/revisit, further explain, mention 'tomorrow we will go back and revisit/review)

Examples of formative assessment: Gather data on student understanding during lesson via warm-ups, graphic organizers, collaborative activities, short quiz, polls, open-ended questions, multiple-choice questions, exit/admit tickets, student responses on individual white boards, can include student responses via technology to identify student strengths and weaknesses.

5. Teacher provides 2 or more opportunities for formative assessment and makes instructional adjustment(s).

4. Teacher provides 2 or more opportunities for formative assessment, but instructional adjustments are not evident.

3. Teacher provides 1 opportunity for formative assessment and makes instructional adjustment(s).

2. Teacher provides 1 opportunity for formative assessment, but instructional adjustments are not evident.

1. Teacher does not provide opportunity for formative assessment.

17. **Science Inquiry**. Does the teacher provide opportunities for students to develop science concepts through scientific inquiry?

Inquiry: Students make observations, propose questions, plan simple investigation, conducts simple investigation, research topic, gathers evidence from observation, considers new evidence, provides explanations based on evidence, analyzes results, records results, communicates findings

5. Teacher provides 4 or more opportunities for students to develop science concepts through inquiry.

4. Teacher provides 3 opportunities for students to develop science concepts through inquiry.

3. Teacher provides 2 opportunities for students to develop science concepts through inquiry.

2. Teacher provides 1 opportunity for students to develop science concepts through inquiry.

1. Teacher does not provide opportunity for students to develop science concepts through inquiry.

Factor 4: Student Engagement and Interaction

18. **Technology.** Does the teacher provide opportunities to engage students using educational technology? For example: teacher use may include utilizing power point presentation, smartboard presentation, online or virtual science demonstrations, simulations, videos. Student use of hardware **-** computers, tablets to access educational software, platforms, curriculum resources, virtual field trip, online interactions, utilize camera to take related pictures, records video.

5. Teacher provides 4 opportunities to engage students through technology, including at least 2 opportunities for students to utilize technology.

4. Teacher provides 3 opportunities to engage students through technology, including at least 1 opportunity for students to utilize technology.

3. Teacher provides 2opportunities to engage students through technology, including at least 1 opportunity for students to utilize technology.

2. Teacher use of technology only.

1. No use of technology.

19. **Student Reflection on Learning**. Does the teacher provide opportunities for students to reflect on their thinking and learning of science concepts?

Examples: Think about what you already know. What did you learn today? How did your thinking change? What is something new that you did not know before? What is the most important thing you learned today? What was something that surprised you? What made you curious today? What do you want to learn more about? And why?

5. Teacher provides 2 or more opportunities for students to reflect on their thinking AND students identified way(s) in which their thinking was reinforced or changed.

4. Teacher provides 2 or more opportunities for students to reflect on their thinking, but students did NOT identify way(s) in which their thinking was reinforced or changed.

3. Teacher provides 1 opportunity for students to reflect on their thinking AND students identified way(s) in which their thinking was reinforced or changed.

2. Teacher provides 1 opportunity for students to reflect on their thinking, but students did NOT identify way(s) in which their thinking was reinforced or changed.

1. Teacher did not provide an opportunity for students to reflect on their learning.

20. **Engaging Questioning Strategies.** Engaging questioning strategies. Does the teacher encourage students to actively participate by implementing engaging questioning strategies to promote discussion between students and to give equal opportunity for all students to respond?

Examples: 1. Think time, 2. Opportunity for all students to respond (pair share, choral response, visual cues, write/illustrate on dry erase board, respond in journal) 3. Random selection of students to share out with class (selected via student names on craft sticks, technology randomizer app) 4. Specific content feedback (connecting feedback to task **-** Great job contrasting living and nonliving).

5. Teacher provides opportunities for students to respond to questions using all 4 of the engaging questioning strategies.

4. Teacher provides opportunities for students to respond to questions using 3 of the engaging questioning strategies.

3. Teacher provides opportunities for students to respond using at least 2 of the engaging questioning strategies.

2. Teacher provides opportunities for students to respond to questions using 1 of the engaging questioning strategies.

1. Teacher does not provide an opportunity for students to respond using engaging questioning strategies.

21. **Students Use of Hands-on Science Materials**. Student use of hands-on science materials. Does the teacher provide opportunities for students to use hands-on science materials/manipulatives to enhance student engagement and learning?

5. Teacher provides opportunities for students to use hands-on science materials/manipulatives (students utilize materials/manipulatives used in stations/centers, students do the work, student exploration) with the teacher as a facilitator (provides resources, monitors progress, helps keep groups focused, circulates and asks questions, encourages students to problem solve)

4. Teacher provides opportunity for students to use hands-on science materials/manipulatives with a high level of teacher guidance (step-by-step, teacher centered).

3. Teacher provides opportunity for students to use hands-on materials but does NOT actively monitor/support (teacher passively observes).

2. Teacher uses hands-on science materials for teacher demonstration only.

1. No use of hands-on science materials.

22. **Peer Collaboration**. Does the teacher provide opportunities for students to work collaboratively during science activities (partner/group work to solve a problem, complete a task, create a product) AND actively monitor/support (provides resources, monitors progress, helps keep groups focused, circulates and asks questions, encourages students to problem solve)

5. Teacher provides 2 opportunities for students to work collaboratively during science activities AND actively monitors/supports group work.

4. Teacher provides 2 opportunities for students to work collaboratively but does NOT actively monitor/support (passively observes) group work

3. Teacher provides 1 opportunity for students to work collaboratively during science activities AND actively monitors/supports group work.

2. Teacher provides 1 opportunity for students to work collaboratively during science activities but does NOT actively monitor/support group work.

1. Teacher does not provide opportunities for students to work collaboratively.