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Scaling Teachers' Professional Development for ASSISTments

INTRODUCTION

The team from Worcester Polytechnic Institute (WPI) that developed ASSISTments—an online homework tool that supports teachers and students with just-in-time feedback and dynamic reports—in partnership with Lesley University and WestEd, proposes a mid-phase Education and Innovation Research (EIR) grant to scale the implementation of this proven intervention to a large, diverse group of schools serving high-need middle school students in predominantly rural areas.

The ASSISTments platform provides *assistance* and *assessment* as students complete their assignments. As they work through homework problems on paper and enter their answers into ASSISTments, the system provides immediate feedback about whether their answers were right or wrong and offers additional assistance in the form of hints or scaffolds. Students' performance on these problems then serves as an assessment of proficiency for teachers; with easy access to detailed student- and class-level formative assessment data, teachers can adjust classroom instruction and pacing to match the knowledge base of the class.

The overall goal of the proposed project is to implement, refine, and evaluate the proven ASSISTments approach in a variety of settings, including high-need rural populations, and develop strategies to improve the sustainability and scalability of the program. To scale up the implementation, the proposed team will 1) **improve the user experience** by implementing design changes to the system to support adoption and implementation by both teachers and students; 2) **create online professional learning (PL)** by developing *ASSISTments Virtual Professional Learning Communities (Virtual-PLC)* to replace the *Visiting Coach Training Method* to remove barriers associated with travel and scheduling; 3) **offer instructional**

supports by creating daily *instructional recommendations* that interpret assessment data and provide suggested short-lesson ideas; and 4) **study the effects of the intervention** by conducting a large-scale school-level randomized controlled trial to test the efficacy of ASSISTments on teachers' classroom practices and students' learning outcomes.

ABSOLUTE AND INVITATIONAL PRIORITIES

Absolute Priority 1—Moderate Evidence: A variety of studies, conducted both internally and externally, have found ASSISTments to be highly effective at improving student outcomes in middle school mathematics. Specifically, use of ASSISTments has been shown to reliably improve students' learning in comparison to business-as-usual conditions in five different preliminary studies (Mendicino, Razzaq, Heffernan, 2009; Koedinger, McLaughlin & Heffernan, 2010; Singh et al., 2011; Kelly, Heffernan, Heffernan et al., 2013; Miller et al., 2013). These five studies led to a rigorous evaluation conducted by SRI, funded by the IES (IES grant R305A120125). Specifically, SRI conducted a year-long, school-level, clustered randomized controlled trial (RCT) with 46 schools. The results indicated that ASSISTments had a significant positive effect on 7th-grade students' math achievement ($p < .008$, $g = 0.18$), and narrowed the achievement gap ($g = 0.29$, Roschelle, Feng, Murphy, & Mason, 2016; see Supplementary Analyses, Appendix H.1). As ASSISTments has been shown to address the achievement gap, scaling the platform is expected to directly impact high-need student populations.

Absolute Priority 3 — Promoting STEM Education

The EIR call under this priority asks for innovations addressing STEM and particularly those addressing the “achievement gap for underrepresented students.” Roschelle et al., (2016) showed that ASSISTments helped to close the achievement gap in mathematics education; while all participating students benefited from ASSISTments, students scoring below the median on the

prior year's state math tests gained the equivalent of more than two years' worth of knowledge while using ASSISTments for one year. Further, the call states that "the Department also encourages expanding access to STEM education in rural areas, especially through partnerships with rural school districts." In the proposed project, we seek to build upon the strong positive effects observed in rural Maine by strengthening our onboarding, training, and support structures for rural teachers in their adoption of this proven initiative.

A. Significance

A.1 The Potential Contribution of the Proposed Project

According to the National Assessment of Educational Progress (NAEP) reports, only 33% of American public school students in 2015 and 34% in 2017 scored at or above proficient in 8th-grade mathematics. This project has the potential to significantly improve students learning outcomes in mathematics. The project builds on an existing teaching strategy by improving how students and teachers engage with homework. Homework is a well-established practice in schools around the country that is thoroughly supported by textbook materials. Yet without explicit interventions, homework is an underutilized tool for improving teaching and learning (APA, 2016). The knowledge base underlying homework's effectiveness in improving student learning is well established, particularly for mathematics. In what is still the definitive meta-analysis (cited 779 times) on the topic of the effectiveness of homework, Cooper, Robinson, and Patall (2006) concluded that the amount of homework students completed was significantly correlated with their achievement outcomes, and that the homework effect was strongest in students in Grades 7-12. Eren and Henderson (2011) then reinforced that mathematics homework had a large positive effect on academic achievement.

Homework provides a key opportunity for individual practice, an undeniably important factor for mathematics learning. Students, especially struggling students, need a way for homework to be differentiated (i.e., adaptable to their needs) rather than uniform (i.e., one-size-fits-all). In addition, students need homework that provides immediate feedback (Hattie & Timperley, 2007), which is rarely available with current instructional practices. Without support at home, it is possible for students to practice mistakes, reinforcing incorrect math strategies and defeating the purpose of homework as a learning opportunity. Evidence has proven that regular homework that can be completed independently and the use of its data by teachers to inform future instruction are vital to adolescents' learning (Fernández-Alonso, Suárez-Álvarez, & Muñiz, 2015). ASSISTments makes these practices possible (Roschelle et al., 2016) connecting teachers and students with feedback and reports that expand student learning and drive instruction.

A.2 Unmet Demand for Technology That Is Proven And Scales

When ASSISTments began in 2004, the demand for online tools to support instruction was infinitely lower than that found today. In 2017, K-12 schools bought eight million Chromebooks to enable schools to move toward online learning (Singer, 2017). More districts are also sending these devices home; the Indiana Tech Plan (2018) survey found that 45% of Indiana school districts (182 of the 397) were sending devices home by 7th grade. That same survey had 191 districts report promotion of open educational resources, or OER. However, providing access itself is not enough (Escueta et al., 2017). To optimize the benefit of technology, well-designed interventions to support teachers' instruction and students' personalized learning are crucial.

As Escueta et al. (2017) indicated in their review of 29 studies that met rigorous standards of randomization, "Two interventions in the United States stand out as being particularly

promising" (page 88) and ASSISTments is one of them. We believe ASSISTments is meeting the unmet demand for proven technology that scales. In fact, we have 30-40 teachers per week requesting an ASSISTments account, but our face-to-face training model cannot keep up with this demand. Teachers are looking for classroom tools that prepare students to take tests online (the new norm). They need such a tool, but one that is designed to support instruction, not just test prep. This project will support schools in acquiring a rigorously evaluated tool that fits their needs in ever changing technology driven classrooms.

B. Quality of the Project Design

B.1 Milestones, Objectives and Outcomes

The four objectives of this project incorporate **scaling up** and **evaluating** ASSISTments as a homework tool to support student learning and teacher instruction. The three activities in objective one support the teacher training needed for objectives two and three which are to feasibly implement and rigorously evaluate the program. Objective four supports dissemination of the findings. All objectives, activities, outcomes, and measures are shown in Exhibit 1.

Exhibit 1. Objectives, Activities, Outcomes, and Measures

| Activities | Outcomes | Measures |
|--|---|--|
| Objective 1. Create & test strategies for improving teacher adoption and implementation | | |
| 1.1 Iterative improvement of user experience supported by interviews with the <i>focus-group teachers</i> . | Changes in the user interface of ASSISTments that allows for easier adoption by teachers and students. | Success rates for teachers and students accomplishing specified tasks. The length of time to accomplish such task and teachers'; self-reports of satisfaction. |
| 1.2 Iterative improvement of the implementation of running Virtual-PLCs. We plan to run new groups using new materials each month. | Facilitation guide for PLC facilitator to use in leading a PLC that introduces ASSISTments as well as influences the participating teachers' implementations. | Increases in teacher retention and adoption of ASSISTments. This is easy to measure as it's collected by the computer. |

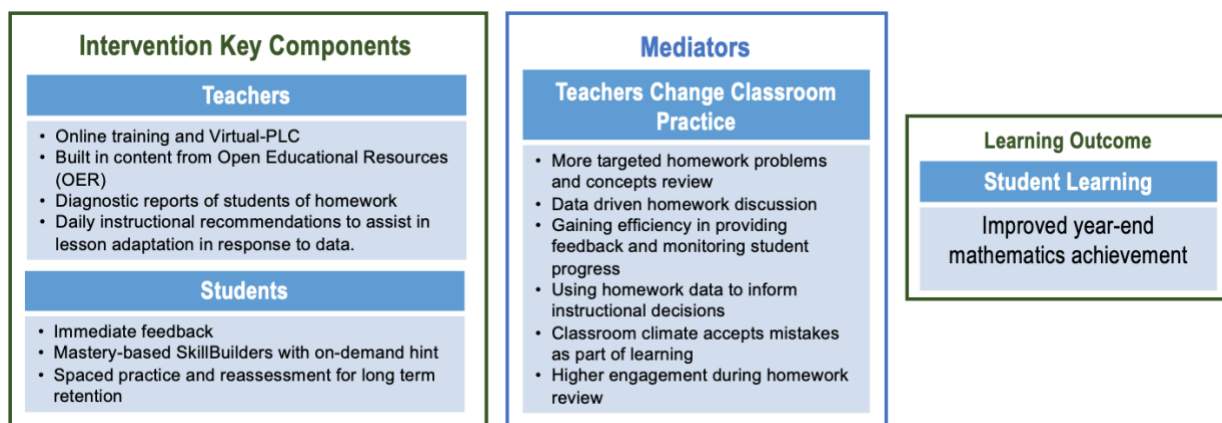
| | | |
|---|--|--|
| 1.3 The creation of Instructional Recommendations and a daily summary to be used to maximize the implementation. | A automated daily summary given to each teacher that gives 1) IR for poor performance and 2) IR for common wrong answers. | Action logs will determine use of IR while thumbs up and down will determine how many are liked by teachers. |
| Objective 2. Implement ASSISTments with the recruited treatment study teachers | | |
| 2.1 Develop a strategic sampling plan that recruits a representative sample of rural schools. | 80 representative schools committed to the study and have agreed to be randomized. | 80 signed memorandum of understanding between districts committing to participation. |
| 2.2 Use new supports from objective 1 to initiate adoption and implementation for Cohort 1 and 2 teachers. | Treatment teachers will attend Virtual-PLCs, assign homework to their students and adjust instruction using the data and Instructional Recommendations | Attendance logs for Virtual-PLC, action logs that measure the number of assignments and the number of times teachers use the reports and IR. |
| Objective 3. Rigorously evaluate the impact of ASSISTments for homework | | |
| 3.1 Randomly assign schools to treatment condition to start implementing ASSISTments or a control condition to continue with existing homework practices. | Samples of treatment and control schools with baseline equivalence in key school-level characteristics. | List of schools and teachers assigned to each condition. WestEd will also create a report on the baseline equivalence. |
| 3.2 Prepare data collection instruments and administration procedures and collect data on teacher classroom practices and student learning outcome. | Data on main outcome and intermediate measures collected; participation rate and attrition rate calculated according to WWC standards. | MRT, Teacher SEC survey, student homework experience surveys, classroom observation protocols, instructional log, administrator interview protocols. |
| 3.3 Measure and analyze implementation fidelity, and explore the relationship between implementation and its effects on learning. | Fidelity and compliance levels analyzed and their relationship with intervention effect analyzed; factors that hinder or facilitate implementation documented. | Implementation fidelity report from WestEd for each key intervention component and strategies according to the implementation compliance thresholds. ASSISTments log data. |
| 3.4 Assess the impact of ASSISTments on teacher classroom practices and student learning outcome. | Data on intermediate and main outcome measures collected and analyzed, following WWC-approved approach. | Study reports of findings on group difference in (a) teacher classroom practices; (b) student math learning outcomes, as well as findings on differential impact and mediation effect. |
| 3.5 Collect cost data and analyze cost-effectiveness. | Findings on cost and cost-effectiveness ratio. | Memo of findings regarding the cost and cost-effectiveness of ASSISTments, comparing to business-as-usual homework practice. |

| | | |
|--|--|---|
| 3.6 Refine materials and procedures. | Improved materials and procedures for recruitment, implementation and participation in online training and Virtual-PLC, data collection. | Records from team meetings; annual report on revisions made to materials and procedures, teacher and student surveys. |
| Objective 4. Disseminate findings and support the infrastructure | | |
| 4.1 Broadly disseminate findings of work on strategies in first three years and final results of impact study. | Increased awareness among school personnel, researchers and policy makers on the findings. | Number of presentations at conferences, webinars, and publications. |
| 4.2 Share findings at annual ASSISTments conferences across the country and on the ASSISTments website. | Teachers need to know the results of the work done for this project. The results will be shared in teacher-friendly terms. | Number of conferences held around the country; number of visits to the ASSISTments website. |
| 4.3 Broadly offer Virtual-PLC support opportunities for individual teachers and districts. | Continued learning of how teachers and districts take advantage of the feedback allowed to them by ASSISTments. | Number of Virtual-PLC's conducted in a year, including the attendance by teachers and district leaders. |

B.2 Conceptual Framework Underlying the Proposed Research

ASSISTments' effectiveness can be attributed to the fact that its features were developed on a strong theoretical and research-based foundation. These are the six theoretical rationales outlined in the project's Logic Model (see Exhibit 2 and Appendix H.2.b).

Exhibit 2. Logic Model



B.2.a Theoretical Rationale for ASSISTments' Approach and Features

a. Tutoring systems for homework: In the Steenbergen-Hu and Cooper (2013) meta-analysis, there were two studies that compared effects of tutoring systems when used for homework against a business-as-usual homework control in which students worked on problems and then waited until the next day to receive feedback (Mendicino, Razzaq, & Heffernan, 2009; Radwan, 1997). Both studies reported large effects (0.6 and 0.4 standard deviations, respectively).

Steenbergen-Hu and Cooper further asserted that “[e]vidence suggests that computer technology appears to have stronger effects when being used as supplemental tools than when used as the only or main instruction” (2013). This statement is consistent with the approach proposed in this project, which is to put the teacher in charge and use computers to support student practice when the teacher is not there (i.e., at home). Furthermore, it has been shown that “online homework increased students’ motivation to complete assignments” (Hunter, 2015).

b. Immediate feedback: Many studies have found meaningful learning gains for students exposed to different types of computer-driven feedback (e.g., Thomas, et al., 2013; McDaniel, Wildman, & Anderson, 2012; Shute, 2008; Jaehnig & Miller, 2007). Findings suggest that students benefit from receiving confirmation that their answers are correct and learning where they erred.

c. Mastery-based learning: With the mastery-learning approach, students only advance to a subsequent learning objective after they have demonstrated proficiency in the current one. Mastery-learning programs have been shown to lead to higher achievement across both high- and low-knowledge students without great time costs compared to more traditional forms of teaching (Kulik, Kulik, & Bangert-Drowns, 1990; Anderson, 2000; Koedinger & Aleven, 2007).

d. Spaced learning: An IES practice guide (Pashler et al., 2007) recommends attending to the spacing of practice and learning over time (Rec.1). A great deal of research (Dunlosky et al., 2013; Cepeda et al., 2009) has shown the benefits of spacing out practice: cramming is ineffective for long-term retention; “the spacing of practice is being grossly underutilized in mathematics instruction,” as Rohrer (2009) noted in a review of the literature.

e. Formative assessment: ASSISTments emphasizes the importance of formative assessment, a process that has been characterized as using student data to inform adaptive changes in instruction (Bennett, 2011; Black & Wiliam, 2009; Brookhart, 2007; Guskey, 2007; Heritage & Popham, 2013). Research documents modest to medium effect sizes of formative assessment on student learning (Black & Wiliam, 2007; Brookhart, 2007; Guskey, 2007; Hattie, 2009; Kingston & Nash, 2012; Shavelson, 2008; Speece, Molloy, & Case, 2003; Thum et al., 2015).

B.2.b ASSISTments for Smarter Homework – How It Works

ASSISTments is a simple yet powerful tool that is used by teachers to free them from tasks that a computer can do while still keeping them in charge. ASSISTments calculates and displays usable assignment data while allowing teachers to focus on planning and teaching. The theories described in Section B.2.a are implemented in concert with the computer and the teacher, each complementing the other. In the next section, the use of ASSISTments is made concrete by describing how 8th-grade math teacher Mike Tarka, who uses the *Illustrative Mathematics* curriculum, uses OER content through the ASSISTments platform. Appendix H.3-6 gives details on the features of which ASSISTments teachers can take advantage.

B.2.c Teacher Uses ASSISTments

Prior to using ASSISTments, Mr. Tarka had been frustrated because students did not seem to learn much from homework assignments; many students repeated mistakes and he had no time to

analyze their answers or to address each child's unique learning needs. He decided to use ASSISTments as a homework intervention since it had content from the *Illustrative Mathematics* curriculum his school had adopted.

He immediately noted some positive changes: 1) students received immediate feedback at home as they worked, leading to *students executing self-regulatory* strategies while revising their independent work; 2) he could use the data report to analyze how each student performed in preparation for homework review and planning his lesson; and 3) in-class homework review became an exciting time to dig into misconceptions, share student work, and appreciate different solution strategies.

To build an assignment, Mr. Tarka began by choosing problems from the *Illustrative Mathematics* curriculum that he wanted to assign. He customized an assignment in ASSISTments by selecting the items, which were uploaded by the ASSISTments' team. His students then accessed the problem set through a link from ASSISTments. They solved the problems on paper and then entered their answers. Initially, his students were frustrated with this step because they were accustomed to doing their homework without needing to worry about the correctness of their answers. With instantaneous feedback, students were required to take their time to fix mistakes. Exhibit 3 shows the student view for a problem set with 11 questions where the student was on #7. The performance bar on the left shows the five different responses the student could receive: 1) red x with yellow background; the student was shown the answer; 2) red x: the student took more than three tries to get the problem right; 3) blue dot: open-response question that is not graded by the system; 4) green x: student answered the problem wrong at first, but got it right after one or two more tries; and 5) green check: student got the problem right on the first try.

Exhibit 3. Student view when using ASSISTments.

First thing in the morning, Mr. Tarka looked at the report from the previous evening's homework assignment (Exhibit 4). This report showed the results for all of his students. Based on the Item Report, he saw that his students did well on the second and fourth problems. In contrast, the average percentage correct for the first problem was low, 34%, and 57% of the of students who got it wrong answered 1.2. Mr. Tarka noticed they had misplaced the decimal in the answer. During the homework review, he shared the data anonymously with his students and discussed the common error, and reflected on how important it was that he and his students were getting this feedback from ASSISTments.

Exhibit 4. ASSISTments Item Report.

| Student/Problem [Anonymize] | Avg | PRAVJF | PRAVJG | PRAVJH | PRAVJD |
|--------------------------------|------|-----------------|----------------|--------------------|-------------------|
| Problem Average | 81% | 34% | 89% | 50% | 91% |
| Common Wrong Answers | | 1.2, 57% | | 6x+4, 45% | |
| Correct Answer(s) | | 12 | 9 | 12x+8 | 1/24 |
| Student One | 92% | ✗ 1.2 66% | ✓ 9 100% | ✓ 8+12x 100% | ✓ 1/24 100% |
| Student Two | 25% | ✗ 0.6 0% | ✗ 7 66% | ✗ x+8 0% | ✗ 3/5 33% |
| Student Three | 66% | ✗ 1.2 66% | ✓ 9 100% | ✗ 6x+4 0% | ✓ 1/24 100% |
| Student Four | 100% | ✓ 12 100% | ✓ 9 100% | ✓ 12x+8 100% | ✓ 1/24 100% |

Based on the data he gathered through ASSISTments, Mr. Tarka also understood that his students needed to attain some “procedural fluency (skill in carrying out procedures flexibly, accurately, efficiently and appropriately),” as noted in the Common Core State Standards (National Governors Association, 2010). He assigned those students some Skill Builders, problem sets that monitor mastery of one skill, for homework. Some students could not figure it out on their own and needed to see Mr. Tarka for help the next day. The report alerted Mr. Tarka so he knew to reach out to those students who needed extra help.

C. Strategy to Scale

C.1 Strategies That Address Barriers To Scale

For the impacts of ASSISTments to scale, the system must be widely adopted and used effectively by teachers on a regular basis. How can we ensure more teachers use the system, effectively throughout the school year? Teachers have many competing demands and need easy-to-use tools that complement their practice and provide information that can be quickly digested and acted upon. In our past work, we have found that time limitations and teacher experience with formative assessment practices as barriers to full adoption of ASSISTments. These barriers can be summarized as barriers around the **1) ease** of use of ASSISTments; **2) accessibility** to professional learning opportunities around using data to inform instruction; and **3) support** for instructional next steps with respect to the data. The current mid-phase EIR will address these past barriers by **1)** dramatically improving the user experience for teachers and students to minimize time for initial setup and daily use; **2)** creating virtual professional learning communities that allow teachers to develop and share best practices around formative assessment without the need for travel or availability at constrained times; and **3)** providing automated

Instructional Recommendations, based on analyses of their own students' data, that save considerable time in determining next steps.

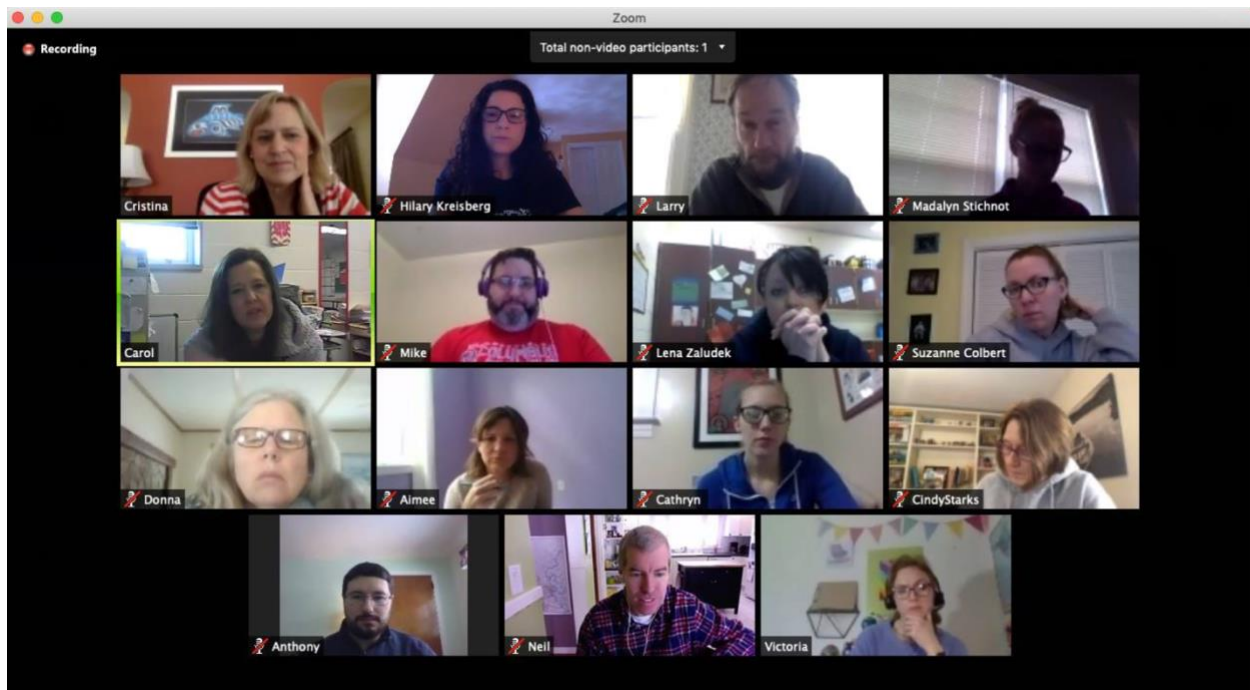
Strategy - Improve User Experience: Teachers have limited time to explore and test new technologies to support learning and need tools to be as easy to use as possible. ASSISTments was designed for teachers and has demonstrated efficacy, however, there is much potential to improve user experience for teachers and students.

Our strategy to improve user experience will involve focus groups, usability studies and iterative design cycles. For teachers to effectively use the system they must complete tasks related to initial setup (helping students get accounts, selecting curriculum) and daily use (assigning homework problems, viewing reports, determining instructional next steps). For students to effectively use the system they need to be able to easily login and complete homework activities. In the past, teachers participated in a full day of in-person training to get started using the online tool; intuitive interfaces should eliminate the need for lengthy training sessions. Based on the findings from the focus groups, we will create paper prototypes of interface sequences to support different task flows (e.g., viewing student reports or completing a homework assignment) and will test these in usability studies with teachers and students. Using an iterative testing cycle we will program prototypes and carry out additional user tests as the designs evolve. As we improve the user experience we do not anticipate any changes to the core functionality of the existing ASSISTments system.

Strategy - Improve Teacher Support and Training: To address the second barrier to scale, **accessibility** to intensive, teacher-centered, collaborative training, we will create Virtual Professional Learning Communities (Virtual-PLC). Professional learning opportunities and teacher training are essential practices for improving teachers' content knowledge and pedagogy

(Cohen & Hill, 2001; Darling-Hammond & McLaughlin, 1995; Smith & O'Day, 1991). In addition, ongoing high-quality professional learning is required by the majority of teaching contracts in the nation (Kennedy, 2016). Research suggests that effective professional learning

Exhibit 5. Personnel conducting a Zoom Training.



needs to be *intensive, teacher-centered, collaborative, job-embedded, data-driven and classroom focused* (e.g., Akiba & Liang, 2016; Darling-Hammond et al., 2014) and professional learning should be accessible and sustainable. We propose a process to create a professional learning system that follows this advice and makes ASSISTments accessible to all teachers.


Our Virtual-PLC will address analysis-of-practice, which has been shown to increase student learning (Taylor et al., 2017). We will experiment with group size and activities to create a robust set of sessions that move from training to support. These sessions will include opportunities for teachers to share best practices and for the facilitator to meet both individually with the participants and as a group.

The Virtual-PLC will address four specific areas of need as recommended by ASSISTments coaches: 1) Finding appropriate content to use with ASSISTments in their classroom; 2) Transitioning from paper-and-pencil to embedding technology in and out of classroom experiences; 3) Using collected data to inform instruction; 4) Supporting the home-to-school connection via communication.

The ASSISTments team has experience with online professional learning. Exhibit 5 shows representatives from The ASSISTments Foundation, Lesley University, and WPI in an online professional learning event with teachers. In another project mentors have found that by holding small group support meetings instead of one to one they have seen an increase in teachers dialogue. This collaboration between teachers who are not geographically co-located has resulted in a change in their practice.

Strategy - Offer Instructional Recommendations based on student data: The third barrier to scale is lack of **data-driven support** to help teachers quickly respond to the data they receive. This support needs to be job-embedded and needs to be focused on the teachers' classroom. We will address this with the creation of the Instructional Recommendation system that will be combined with ASSISTments data to give teachers instructional support that aligns directly to their students' homework results. Teachers will be using one of the three new, increasingly popular, OER curriculum, EngageNY, Illustrative Mathematics, or Utah Middle School Math Project. Our team of *collaborator-teachers* will record and share their instructional recommendations, such as those shown in Exhibit 6.

Exhibit 6. Examples of Instructional Recommendations.

| Situation | IR for common wrong answer  |
|--|--|
| 57% of students answered 1.2 instead of 12. | Provide students with a place-value chart and base-ten blocks and ask them to use place-value language to describe what happens to a number when they divide by 100. |
| 45% of the 50% who got it wrong answered $6x+4$ instead of $12x+8$. | Project the linear equations ($y = 6x+4$ and $y = 12x+8$) on the same graph. Ask students to notice and wonder the similarities and differences between the two lines. |






| Situation | IR for poor performance  |
|---|---|
| Only four students gave completely non-sensible answers on the second problem which was a word problem. | Pull four students for small-group intervention. Conduct a numberless word problem where first, they must read the problem with the numbers covered and the question omitted. Ask students to describe the situation. |
| Percent correct was very low. There were no common wrong answers. | Have you done the warm-up from Unit 2-Lesson 4 in class? If not, we suggest doing so. If you have, try redoing it, but providing manipulatives. |

Exhibit 7. Instruction Recommendation Interface.

| Student/Problem [Anonymize] | Avg | PRAVJF | PRAVJG | PRAVJH | PRAVJD |
|--------------------------------|-----|---|---|---|--------|
| Problem Average | 81% | 34% | 89% | 50% | 91% |
| Instructional Recommendation | |   |  |  | |
| Common Wrong Answers | | 1.2, 57% | | $6x+4$, 45% | |

Curricular materials offer lessons for teaching content, this will be support for teachers in responding to data. The support will be written by teachers for teachers and delivered with the item report (see Exhibit 7) Teachers will be able to comment and converse online about their responses to their students' common wrong answers and their instructional ideas for dealing with these learning deficiencies.

C.2 Increase in Efficiency in the Use of Time, Staff, and Money

ASSISTments was designed to make feedback more efficient for teachers and students. This project with its three strategies is designed to make the process of learning to use ASSISTments and improve instruction in response to the data even more efficient and extremely cost effective. The improvements to the user experience in strategy 1 will allow teachers to more efficiently begin to use the platform, saving money in training, using the tool will be intuitive with helpful online support so there will not be a need for staff to print out instructions or provide costly trainings.

The Virtual-PLC is designed to work in tandem with teachers and facilitator's busy schedules. The face-to-face training model we used in the State of Maine and are using in our current replication of that study in North Carolina involves a personalized trainer traveling to each school and working with the teachers. This current practice is not scalable for three reasons: 1) It is time consuming to travel to schools; 2) There may not be a suitable coach in the vicinity of each school. For example, a coach in North Carolina spends 60% of his time traveling and 40% working with the teachers. In rural districts, where schools are far apart from each other, the ratio of travel to training time would be impractical; 3) in-person professional learning is much more costly than virtual professional learning.

To eliminate travel time for teachers attending training and coaches visiting schools we will iteratively develop Virtual-PLC led by expert trainers but held online using Zoom. These tools have sophisticated screen-sharing options and breakout rooms to allow for rich interactions. McConnell et al. (2012) suggest that Virtual-PLC can channel the benefits of in-person sessions while making professional learning much more accessible.

Strategy 3 is designed to be efficient by capturing one teachers efforts and share it with the community of teachers. Just like with Wikipedia there is no cost, experts share their ideas and others use them. This project will be taking advantage of the highly regarded free Open Source Textbooks. A recent study by RAND showed that over half the teachers in the U.S. have used EngageNY materials (Kaufman et al., 2017). EdReports gave Illustrative Mathematics its highest mark for alignment with the Common Core State Standards (EdReports, 2018). The three OER we will be working with align with the Common Core State Standards that is adopted in part by most states in the nation, and is gaining impressive traction in schools across the country (Tepe & Mooney, 2018). These books are a great value for districts and these free instructional recommendations just add to the appeal.

D. Adequacy of Resources and Quality of Management Plan

D.1 Management Plan, Timeline and Milestones

The project will be led by WPI, in collaboration with the ASSISTments Foundation, WestEd, and Lesley University following the timeline in Exhibit 8. The responsibilities for objective 1 will be divided among researchers at WPI and Lesley University with the ASSISTments Foundation carrying out the work of improving the user experience for the user interface and the Instructional Recommendations. Lesley University will develop the Virtual-PLC program. The work done for objective 1 will influence the teacher support in objective 2. WestEd will conduct the research outlined in Objective 3. The ASSISTments Foundation will lead the outreach to teachers while WPI, WestEd, and Lesley University will reach out to leaders in the field and other researchers. Exhibit 9 indicates how the responsibilities are shared across the four objectives and the five years of the project.

Exhibit 8. Timeline.

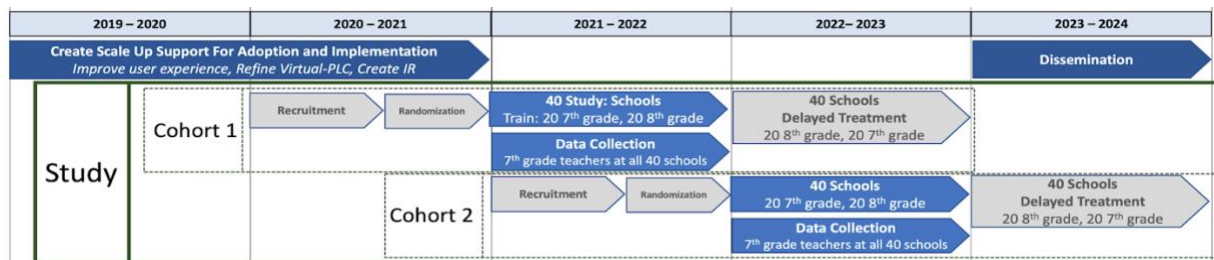


Exhibit 9. Milestones, Timeline and Responsibilities.

| Milestones | Y1 | Y2 | Y3 | Y4 | Y5 | Who is responsible? | Teachers |
|--|----|----|----|------|----|---------------------|----------------|
| Objective 1: Create and test support for teacher adoption and implementation. | | | | | | | |
| Improvement of user experience | x | x | | | | WPI, AF, WE, LU | CT, FT |
| Virtual-PLC Design | x | x | | | | LU, AF, WPI, WE | CT, FT |
| Instructional Recommendations | x | x | | | | WPI, AF, WE, LU | CT, FT |
| Objective 2. Implement ASSISTments with the recruited study teachers. | | | | | | | |
| School recruitment | | C1 | C2 | | | WPI, AF, LU, WE | |
| Teacher support and implementation | | | C1 | C1,2 | C2 | LU, AF, WPI | 1T, 2T |
| Continuous improvement UI, V-PLC, IR, | | | x | x | x | AF, WPI, WE, LU | CT, 1T, 2T |
| Objective 3. Rigorously evaluate the impact of ASSISTments for homework. | | | | | | | |
| Random assignment | | C1 | C2 | | | WE | 1T, 2T |
| Prepare instruments and collect data | | | C1 | C2 | | WE | 1T, 2T |
| Measure implementation fidelity | | | x | x | x | WE | CT, 1T, 2T |
| Assess intervention effects | | | x | x | x | WE | CT, 1T, 2T |
| Refine materials and procedures | | | x | x | x | AF, WPI, WE, LU | CT, 1T, 2T |
| Objective 4. Disseminate findings and support the infrastructure. | | | | | | | |
| Present Findings | | | x | x | x | WE, WPI, LU, AF, | |
| ASSISTments conference, web | x | x | x | x | x | AF, WPI, | CT, FT, 1T, 2T |
| Broadly offer Virtual-PLC | x | x | x | x | x | AF, LU, WPI | CT, FT, 1T, 2T |

Key Institutions and Teams: WPI – Worcester Polytechnic Institute; AF- ASSISTments Foundation; WE - WestEd; LU - Lesley University; CT - Collaborator Teachers; FT - Focus Group Teachers; 1T, 2T - Cohort 1,2 Teachers (for a description of teacher partners see Appendix H.7.b).

D.2 Capacity of the Applicant

The project team is uniquely qualified to carry out the proposed work. The team brings extensive expertise in technology development, teacher professional learning, math education, instruction design, user experience and learning engineering, rigorous and mixed-method research and evaluation. Exhibit 10 details key personnel's role and their experience.

Exhibit 10. Roles, Experience, and Primary Responsibilities of Key Personnel.

| Role in Project | Experience and Primary Responsibilities |
|---|--|
| Worcester Polytechnic Institute Personnel | |
| PI Dr. Neil Heffernan Project Director 8% - Years 1-5 | Dr. Heffernan is a Professor at WPI in Computer Science, and Director of Learning Sciences & Technologies program. He has been awarded approximately \$1 million a year as PI/Co-PI since 2002 to develop ASSISTments and conduct research in it. <ul style="list-style-type: none"> Will oversee and direct the project. |
| Project Coordinator | Tracked and implemented activities in a timely manner* |
| Erin Ottmar | Math Education Research Advisor: Will advise on creation of IR* |
| Lane Harrison | User Experience Research Advisor: Research on user experience* |
| ASSISTments Foundation Personnel | |
| Cristina Heffernan Executive Director 50% - Years 1-5 | Cristina Heffernan has a strong background teaching and coaching middle school math, including seven years of teaching middle schools in various settings. Ms. Heffernan earned a Master's Degree in Math Education working with Dr. Peg Smith, author of one of the best-selling books on instruction. This experience has helped the Heffernan's create a tool that is truly meant for teachers to support teaching and learning. <ul style="list-style-type: none"> Manage the ASSISTments Foundation's role in the project. Oversee the programmers as they implement the activities outlined by the team members. Oversee communication with all participating teachers. |
| David Magid | Lead System Manager: Develop and supervise improvements*. |
| Chris Donnelly | Software Engineer: Lead user-experience software engineer* |
| User Experience | Support Dr. Harrison and Cristina Heffernan with user-experience updates.* |
| Continuous Improvement | Manage Continuous Improvements of the UI, Virtual-PLC and IR* |
| Lesley University Personnel | |
| Hilary Kreisberg Chief Teacher Trainer Lesley University 31% | Dr. Kreisberg is the Director of the Center for Mathematics Achievement at Lesley University and the President of the Boston Area Mathematics Specialist organization. She is an expert in the field of mathematics education and is highly sought after as a coach and curriculum developer, particularly in low-income districts. <ul style="list-style-type: none"> Design and implement the Virtual-PLC with the <i>cooperating teachers</i> and the <i>focus-group teachers</i>. Work in-tandem with the Instructional Recommendations Manager to ensure that recommendations are research-based and appropriate according to mathematical learning trajectories. |

| | |
|---|--|
| Brittany Gonio | Manage the rounds of Virtual-PLC's offerece during Years 1 and 2.* |
| Virtual-PLC Facilitator | Manage and Facilitate the Virtual-PLC.* |
| Virtual-PLC Designer | Design high quality focused on deepening mathematics content knowledge.* |
| Evaluation Key Personnel WestEd | |
| Mingyu Feng Evaluation Director, 28% | Dr. Feng is a Senior Research Associate with the STEM program at WestEd. She leads several large-scale implementation and impact studies of technology-based education interventions, using a mixed-method approach. She also conducted research in design and development of intelligent tutoring systems and carried out analysis of system data. <ul style="list-style-type: none"> • Direct the evaluation and the impact study. • Lead implementation fidelity measures and analysis. |
| Jodi Davenport | Lead Analyst: Lead formative evaluation.* |
| Linlin Li | Lead Methodologist: Lead impact study and outcome analysis.* |

* For more information see Appendix H.7

D.3 Continued Support of the Project after Federal Funding Ends

The newly created ASSISTments Foundation™ is perfectly situated to supporting the continuation of the scale-up efforts once this project is complete. Currently the ASSISTments Foundation has funding from the Chan Zuckerberg Initiative for \$ [REDACTED] and the Schmidt Foundation for \$ [REDACTED]. WPI has used that funding to create this spin-off, mission-focused, non-profit entity to deliver ASSISTments to more districts. The ASSISTments Foundation™ will offer fee-based services, such as professional learning and training at a nominal cost to teachers and districts. WPI has licensed the ASSISTments trademark and codebase to the ASSISTments Foundation that works hand-in-hand with WPI, allowing Dr. Heffernan to continue to conduct research. Schools and districts will purchase the opportunity to be a part of a Virtual-PLC while using ASSISTments and the Instructional Recommendations free of charge.

D.4 The Extent to Which The Project Is Reasonable in Relation to the Objectives

We believe that it is highly feasible to replicate and expand the implementation of ASSISTments and its professional learning model in a variety of settings and populations and at a reasonable cost for several reasons. First, **ASSISTments builds upon existing school policies and practices so there is no cost of changing existing initiatives.** Our theory of change relies on a

decision to position ASSISTments as online support for mathematics homework, a malleable factor which is already required in schools and expected by students and parents (Fairman, Porter, & Fisher, 2015; Juster, Ono, & Stafford, 2004; Loveless, 2014), but is somewhat controversial and perceived as needing improvement (Kohn, 2006; Bennett & Kalish 2006; Galloway & Pope, 2007; Fernández-Alonso et al. 2015; Trautwein & Koller, 2003). The intervention fits within existing school policies and practices and expectations about the time teachers and students should spend on homework (Fairman, Porter, & Fisher, 2015), utilizes existing textbook materials, and does not require costly change to existing instructional approaches, making ASSISTments relatively inexpensive to adopt. Second, during previous and current studies **ASSISTments has been successfully implemented with fidelity** in various settings with different populations in over 50 rural, suburban or urban public or charter schools in Maine and North Carolina. Third, the proposed **virtual online professional learning** provides a way for teachers to gather and learn without costly long-distance travel, which further enables the expansion of ASSISTments in distant rural areas. The ASSISTments Foundation will offer the Virtual-PLC at a minimal cost to districts, and will continue to build the online community of professional learning to help teachers support each other with successful implementation. Fourth, this project will result in **pre-built homework materials and well-developed Instructional Recommendations for the free OER** that are readily available to support the roles of teachers. Tools and platforms will be developed to build more resources for districts that are considering adopting ASSISTments.

E. Project Evaluation

An independent team of highly experienced researchers from WestEd will provide formative and summative information throughout the five-year project. The evaluation will consist of two

components. The **formative component of evaluation**, aimed at augmenting WPI's development and continuous improvement of the ASSISTments program, will be led by Dr. Jodi Davenport, who is an expert in mathematics education and visual cognition. She directed the research of the National Center on Cognition and Mathematics Instruction and has extensive experience with developing education technology, formative assessment, and studying teacher experience. The formative evaluation will be guided by research questions around both the process and progress of the study. Process-related questions include: *Are the samples of teachers and students in the user-experience studies representative and adequate? Are the newly developed Virtual-PLC and Instructional Recommendations appropriately vetted and achieving their objectives?* Progress-related questions include: *Are project milestones being met as intended? Are the iterations of development improving quality and ease of use?* To address these questions and provide formative feedback during Years 1-3, Dr. Davenport will participate in regular meetings with the project directors, interview collaborators across institutions, teacher participants and co-developers, and other key stakeholders, conduct a comprehensive review of project materials and iterative development plans, and offer timely recommendations.

The **summative evaluation component** will include a rigorous randomized controlled trial (RCT) to measure the impact of ASSISTments on 7th-grade mathematics learning, as well as quality and fidelity of implementation of the intervention in 80 schools of diverse population and settings. The study will be led by Dr. Mingyu Feng who served co-PI on the completed RCT that examined efficacy of ASSISTments in Maine (IES R305A120125) and is currently serving as PI of the replication study of ASSISTments in North Carolina (IES R305A170641). She will be supported by Dr. Linlin Li who is a WWC-certified reviewer and served as co-PI on I3 and EIR evaluations. Building on prior efficacy trials (see Appendix H.1), the study is designed to 1)

yield impact estimates of ASSISTments on instructional practices and learning outcomes for a diverse population; 2) offer evidence of generalizability of the intervention, 3) examine implementation in more detail, especially the newly introduced components, namely Virtual-PLC and Instructional Recommendations, and 4) provide guidance to the adoption and replication of the innovative intervention in other settings.

E.1. Methods Designed to Meet WWC Standards Without Reservations

WestEd will conduct an independent impact study to address five research questions that are aligned with ASSISTments logic model (see Appendix H.2a), about the program’s impact, implementation and cost effectiveness. RQ1 address the effects of ASSISTments on students’ mathematics achievement. RQ2 focuses on the differential effects of ASSISTments on different types of students. RQs 3-4 examine the impact of ASSISTments on teachers’ classroom practices, and how changes in teacher’s practices mediates the intervention’s effect on student learning. RQ5 focuses on assessing implementation fidelity and quality.

Exhibit 11. Summative Research Questions, Outcomes, & Measures.

| Research Questions | Outcome | Data / Measures |
|--|-------------------------------------|---|
| <i>(RQ1) Outcomes.</i> Do students in schools that use ASSISTments for homework learn more than students in schools that do homework without ASSISTments? | Students’ mathematics achievement | State 6th- and 7th-grade assessments scores; MRT 8 th -grade Readiness Test; Student and school demographics |
| <i>(RQ2) Moderators.</i> Do the effects of ASSISTments vary for students with different prior achievement, and for students of different socio-economic status, race/ethnicity, or with other policy-relevant characteristics? | | |
| <i>(RQ3) Impacts on adjustments to classroom instruction.</i> Do teachers use ASSISTments reports to adjust their homework review and classroom instruction? | Teacher’s classroom practices | Classroom observations, SEC surveys Instructional logs |
| <i>(RQ4) Mediators.</i> Do teachers’ adjustments to homework review and classroom instruction mediate the effects of ASSISTments on student learning? | | |
| <i>(RQ5) Implementation fidelity and effects of implementation on student learning.</i> Do participating schools implement ASSISTments as intended by the developer? How much usage occurs? To what extent is each feature used? What are the effects of implementation fidelity and dosage on learning? What are the factors that hinder or facilitate implementation? | Implementation fidelity and quality | Computer log data of usage; Observation protocols; Teacher surveys; Instructional logs |

Study design. The study will use a school-level, delayed-treatment, clustered randomized controlled experimental design, to meet What Works Clearinghouse standards without reservations (WWC, 2017). The RQs will be addressed with data collected from two consecutive cohorts of schools. Each cohort will include 40 schools that will be randomly assigned to a treatment condition where all 7th grade teachers in the school will use the ASSISTments platform to support math homework or to a control condition. In the control condition, teachers will continue their current homework practices (business-as-usual), including any use of online tools, but not ASSISTments. After the experiment is completed, control schools will also have access to ASSISTments. Student rosters will be collected two weeks prior to the start of each school year. Students who join study schools during the school year will be excluded from the evaluation sample. The team will track both overall and differential school- and student-level attrition from both conditions (see Appendix H.8 for Timeline of Impact Evaluation).

Sample and power. The team will recruit 80 public schools in rural districts that have adopted OER curriculum for mathematics. We will gather data on school characteristics to identify possible stratification variables (e.g., the percentage of students who achieved mathematical proficiency on prior tests, percentage of low-income students) to improve precision and sample balance across groups. With supported from consultant Dr. Elizabeth Tipton, we will develop a plan for recruiting a representative sample to increase the generalizability of the results of the study, with a focus on involving high-need rural schools, low-performing schools and schools with lower-socioeconomic-status student bodies. A power analysis was conducted using PowerUp! (Dong & Maynard, 2013) for random assignment designs with assignment at the school level. Assuming an average of two math teachers would be recruited at each school in 7th

grade, with 50 students each, the proposed study has sufficient power to detect effects of 0.167 standard deviations on student achievement (see Appendix H.9 for justification).

Data Analysis Plan. To estimate the impact of ASSISTments on student achievements, the study team will conduct an intent-to-treat (ITT) analysis using a three-level model with students' nested classrooms, and in schools. Continuous scaled scores in 6th and 7th grade from different states will first be transformed into z-score units for comparability across states. Analyses will test the overall impact of the intervention for 7th-grade students, as well as the interventions' differential effects on students and schools with different characteristics. To improve the precision of the impact estimate, each model will adjust for blocking (by cohort and district), a baseline measure, other student, teacher, and school characteristics (see details of the data analysis plan in Appendix H.10).

E.2. Generation of Guidance About Effective Strategies Suitable for Replication

The proposed study is designed to generate insightful guidance for successful replicating and scaling ASSISTments in other schools and districts broadly in four aspects. First, WestEd will **strategically sample** and recruit a large number of schools representing diverse settings and plans to conduct interviews with school administrators to **document the context of implementation**, such as district priorities, adoption status of technology, homework policy, school-level support and cultures for data use, teacher collaboration and professional learning.

Secondly, the evaluation included **differential impact analysis** (RQ2) to assess to what extent the impact of ASSISTments is moderated by the characteristics of students (e.g., ethnicity, English-language learners, eligibility for free or reduced-price lunch, IEP), or schools (e.g., school type—K-8 vs. 6-8, locale, demographic composition, years adopted 1:1 computer program) and to identify for which settings or populations the intervention is particularly

effective. ASSISTments was designed to help teachers identify and provide intensive instructional support to struggling learners and has been found a potential to close achievement gaps. WestEd will be further investigated this during the impact study.

Thirdly, the study builds in **analysis of implementation data from multiple sources** (RQ5). The essential features of implementation that should be followed by future efforts to replicate or extend this intervention include 1) participation in online training, and Virtual-PLC; 2) making homework assignments within ASSISTments multiple times per week; 3) reviewing homework performance summary, reports, and Instructional Recommendations; 4) adjustment in homework review and instructional practices in classrooms. Accordingly, data will be collected on all four aspects. We will examine implementation fidelity based on professional learning records, ASSISTments system logs of usage, classroom observations, teacher self-reported pre- and post-surveys as well as instructional logs (see Appendix H.11 for details and Appendix H.12 for data collection timeline). In particular, we will focus on the **fidelity of the scaling-up approaches** proposed in B.2 and identify facilitators and barriers to implementation of the intervention.

Lastly, policymakers and educational administrators require information on the cost of the resources needed to adopt, implement particular instructional interventions with fidelity, and to sustain the interventions. To provide information about whether ASSISTments is more cost effective, comparing to business-as-usual homework practices, WestEd will conduct a **cost analysis** and calculate a **cost-effectiveness** ratio. Costs will be gathered systematically using the “ingredients method” as described in Levin and McEwan (2001). Once all of the ingredients are identified, we will use *CostOut* - the CBCSE Cost Tool Kit (Hollands et al., 2015) to facilitate the estimation of costs and cost-effectiveness. (see Appendix H.13 for details of cost analysis plan).

E.3. Valid and Reliable Performance Data on Relevant Outcomes

The evaluation team seeks to triangulate multiple data sources to reinforce validity of the findings. Appendix H.14 includes a summary table of outcome measures, validity, and reliability).

Student Outcomes. As shown in the logic model, the key student outcome of ASSISTments is academic achievement. The **primary student learning outcome measure** will include 7th-grade statewide mathematics assessment scores from spring 2022 (Cohort 1) and spring 2023 (Cohort 2), using the relevant accountability measures of math achievement within each state. WestEd will secure agreements with participating districts to obtain the extant mathematics state test scores in both 6th (as covariate) and 7th (as outcome) grades, as well as demographics. Additionally, we propose to use the Common-Core aligned Grade 8 Mathematics Readiness Test (MRT) developed by the Mathematics Diagnostic Testing Project (MDTP) as a **supplemental measure** to gauge students' readiness for 8th grade at the end of the study across all. The MRT has been reviewed for reliability and validity (Anthony, 2005). The test will be administered online via the MDTP Online Testing Platform to all students in both treatment and control groups in spring 2022 (Cohort 1) and spring 2023 (Cohort 2), right at the end of 7th grade.

Classroom Outcomes: Homework Review Practices and Classroom Climates. Teacher homework review practices and changes in classroom climates (RQ3) will be assessed by a) classroom observations using the protocol that was developed and validated during other ASSISTments efficacy studies (see Appendix H.15 for a portion of the observation protocol.) For each cohort, WestEd will sample 15 treatment classrooms and 10 control classrooms for observation in the spring; and b) the Survey Of Instructional Practices (Teacher Survey for Grades K–12 Mathematics), a part of the *Surveys of the Enacted Curriculum* (SEC) data tools

(WCER, 2012). (see Appendix H.16 for a portion of the SEC teacher survey). The SEC has demonstrated itself to be a valid and reliable instrument for measuring key aspects related to teachers' delivery of their instructional practice (Porter, Kirst, Osthoff, Smithson, & Schneider, 1993). The overall reliability coefficient for the instrument ranges from 0.72 to 0.87. All treatment and control teachers will take the SEC survey online in summer (as baseline), before treatment teachers receive professional learning, and again at the end of the year.

In addition, each teacher will be asked to fill out instructional logs on homework practices in four researcher-selected weeks. Teacher self-reported survey and log responses will be triangulated with other sources of data (e.g., system data, observations) for confirmation of teacher activities. A short survey will be administered to a sample of 20% of students in spring asking students about their experience with completing homework online (treatment) or on paper (control), how they receive feedback on homework, and their role during homework review.

E.4. Components, Mediators, Outcomes, and Measurable Threshold for Implementation

Components, Mediators and Outcomes. The design of the evaluation is informed by the key components, mediators, classroom and student learning outcomes as illustrated in the logic model in Exhibit xx. The key components of ASSISTments on the teacher side include the use of online training and Virtual-PLC to help teachers learn about ASSISTments and address their questions and concerns in a collaborative manner, providing pre-built content from OER to make it easy for teachers to select relevant and timely practices for homework assignment, informing teachers of students' strengths and needs via diagnostic reports, and providing Instructional Recommendations to assist teachers with instruction adaptation. Key intervention components for students include immediate feedback, spaced practice and reassessment of math knowledge to enable long-term retention, and mastery-based practice. Based on prior findings (Fairman et

al., 2016), we hypothesized that the intervention will lead to more targeted homework review practices and higher student engagement during homework review (RQ3), which will mediate the intervention's effect on students' mathematics achievement (RQ4).

The system records of all student and teacher actions will serve as a primary source of data in assessing the extent to which ASSISTments is used according to the specified use model.

WestEd will also collect data on teachers' attendance of professional learning sessions. Referring to the framework by Weiss, Bloom, & Brock (2014), with support from our advisor, Dr. David Cordray, WestEd will refine the implementation metrics developed in prior studies (Feng et al., 2014; see Appendix H.17 for the indices), and set associated thresholds of implementation fidelity for each metric. There will be metrics for three types of **indicators of implementation compliance**—one based on intensity and continuity of student/teacher homework use, one on the extent to which teachers use the analytic tools, Virtual-PLC, and Instructional Recommendations, and a third on the extent to which teachers customize the content and activities to students. The metrics will cover four categories of implementation fidelity associated with key components of the intervention, namely adherence, exposure, quality of delivery, and uptake (Cordray, 2008). The **minimum acceptable implementation** thresholds are defined as follows, based on what we've learned from prior studies. Teachers are expected to participate in the initial online training and to attend at least 40% of the Virtual-PLC sessions, accumulating to at least 20 hours of professional learning time. Teachers are expected to assign homework at least two days per week and to review reports for at least 50% of the homework assignments. During the school year, WestEd will calculate the implementation metrics at the individual teacher level quarterly and share the results with the developers to inform continuous improvement.

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