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Scaling Teachers' Professional Development for ASSISTments

Evaluation Final Report

Mingyu Feng, Linlin Li,
Natalie Brezack, Chun-Wei Huang,
Kim Luttgen, Jenna Grady,
Shuangting Yang, Abby Lavine,
Kelly Collins, Megan Schneider

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Introduction

Math education continues to be a central priority for improving educational outcomes in the United States, particularly in light of the widespread learning loss caused by the COVID-19 pandemic. In 2023, fewer than 50 percent of 6th grade students were performing at grade level in math (Curriculum Associates Research, 2023), and national data show a decline in 8th grade math scores from 2019 to 2022 (The Nation's Report Card, n.d.). These challenges are especially critical in rural schools and districts, which make up over half of U.S. districts and serve roughly one third of the nation's students (Johnson et al., 2014), including 15.4 percent who live in poverty (Showalter et al., 2019). Rural areas often experience "rural brain drain" when educators leave rural districts for opportunities in other areas (Fishman, 2015), which can leave remaining teachers professionally isolated—sometimes as the sole educator for a subject or grade level in their region. This isolation, combined with logistical hurdles such as limited access to professional development, long travel distances to in-person training, and difficulty finding substitute teachers, creates significant barriers to instructional improvement.

To address these multifaceted challenges, it is critical to identify and scale research-based strategies that can improve math instruction across diverse educational contexts. One program that responds directly to the need for scalable, evidence-based solutions is ASSISTments, an evidence-backed educational technology program designed to enhance math instruction and student learning (Feng et al., 2025; Roschelle et al., 2016). As the demand increases for solutions that are both effective and scalable, ASSISTments offers an illustrative case of supporting teachers in successfully implementing evidence-based digital programs. Previous research has demonstrated its effectiveness at supporting teachers in engaging students in data-based math discussion, making data-driven instructional decisions, and integrating the ASSISTments platform seamlessly into their classroom routines as part of technology-enabled learning (Albion et al., 2015; Singh et al., 2022).

Supported by a grant from the U.S. Department of Education's Education Innovation and Research (EIR) program, Worcester Polytechnic Institute (WPI) collaborated with Lesley University to enhance and scale the ASSISTments intervention. This intervention, virtual professional learning community (vPLC)–augmented ASSISTments, combines WPI's ASSISTments online math platform (Heffernan & Heffernan, 2014) with a vPLC designed to enhance the scalability of the program. To evaluate this intervention's effectiveness, WestEd conducted a national study to (a) describe how the ASSISTments intervention was adapted and expanded from its original form to a more scalable model that incorporates vPLC supports for broader implementation and (b) examine the impact of the intervention on math achievement in rural, high-needs middle school settings.

This report describes the intervention, including the ASSISTments platform for students and teachers, and the design, structure, and content of the vPLC. It then outlines the research design, participants and settings, measures, and analytic methods and then describes results addressing seven research questions. The report concludes with a cost-effectiveness analysis.

Relevant Research Evidence

This section draws on evidence from several key areas—independent practice and formative assessment, the use of high-quality curricula, sustained professional learning communities (PLCs), and rigorous evidence from large-scale implementations—to highlight scalable approaches that strengthen instructional quality, support teacher practice, and improve student outcomes in mathematics.

Independent Practice and Formative Assessment

Effective mathematics instruction depends not only on what teachers deliver during lessons but also on what students do on their own and how teachers respond to students' understanding (Misfeldt et al., 2024, Rosenshine, 2012). Two widely used strategies that support math learning are *independent practice* and *formative assessment* (Bennett, 2011; Irons & Elkington, 2021; Rosenshine, 2012).

Independent practice refers to opportunities for students to apply and reinforce skills or concepts on their own, usually after receiving initial instruction (Cooper et al., 2006; Marzano, 2007; Rosenshine, 2012). This practice can occur during class or as homework and is intended to help students develop fluency, build confidence, and move toward mastery of the material (Rosenshine, 2012). Independent practice supports learning by allowing students to engage actively with content, apply problem-solving strategies, and internalize new knowledge through repetition and self-direction (Cooper et al., 2006; Marzano, 2007). Research shows that regular engagement in independent practice is positively associated with academic achievement. For example, students scored higher on a standardized math test when their teachers devoted more class time to independent practice and assessment, regardless of the quality of the teachers' instruction (Burgess et al., 2023).

On the other hand, *formative assessment* is a process by which teachers gather and use evidence from student work to inform instructional decisions, better address students' needs, and support ongoing learning (Black & Wiliam, 2009; Cizek et al., 2019; Klute et al., 2017; Lembke & Stecker, 2007; Martin et al., 2022). Formative assessment is not about the task itself but rather about how the teacher uses the results to adapt instruction. It can range from informal techniques, such as asking probing questions during a lesson, to more structured approaches, such as reviewing student quiz data or analyzing trends in homework performance (Black & Wiliam, 2009; Cizek et al., 2019; Irons & Elkington, 2021; Klute et al., 2017). Recent studies have highlighted the positive impact of formative assessment on student achievement in mathematics, emphasizing its role in identifying misconceptions and adapting instruction in real time (Andersson & Palm, 2017; Misfeldt et al., 2024).

While both independent practice and formative assessment are critical for learning, their success depends on the quality and timeliness of feedback and data. This creates a clear need for educational technologies that can close the gap between student work and instructional decision-making.

The Need for Immediate Feedback to Support Student Learning During Independent Practice

One major limitation of traditional paper-based independent practice is the lack of timely, corrective feedback. When students complete work independently without receiving feedback, they may practice incorrectly and reinforce misconceptions (Mendicino et al., 2009). In contrast, immediate feedback helps students recognize and correct mistakes as they occur, which can support their learning process, foster deeper conceptual understanding, build confidence, and keep them engaged. Research consistently supports the value of immediate, elaborated feedback, which not only tells students whether they are correct but also provides hints, explanations, or additional resources to guide their understanding. A meta-analysis by Van der Kleij and colleagues (2015) found that this type of feedback produced significantly greater learning gains than simple correctness feedback, with an effect size of 0.49.

In addition to supporting mastery of content learning, immediate feedback also plays a key role in fostering self-regulated learning (SRL), the cognitive and metacognitive processes students use to plan, monitor, and reflect on their learning (Winne & Hadwin, 1998; Zimmerman, 2000). SRL includes three phases: preparation, performance, and appraisal (Panadero, 2017). Students engage in specific actions throughout the phases, including goal setting, strategy selection, performance monitoring, and self-evaluation (Panadero, 2017). All these actions are strengthened when students receive real-time feedback that helps them assess progress and adjust their approach. Research has shown that SRL is closely linked to academic achievement, especially when students develop motivation, persistence, and positive beliefs about learning from mistakes (Dignath et al., 2008; Jackson et al., 2022; Tulis et al., 2018; Wang & Sperling, 2020). When feedback helps students recognize and correct errors, it not only deepens understanding but also reinforces their sense of control and agency in the learning process.

A promising way to support both mastery learning and self-regulation learning is through technology-based platforms that embed scaffolded, feedback-rich independent practice. These tools offer structured opportunities for students to persist through challenging problems, correct errors before moving on, and access tiered hints or explanations as needed (Roll et al., 2014; Van der Kleij et al., 2015). By aligning independent practice with mastery-based expectations and self-monitoring supports, digital platforms can transform routine exercises into meaningful learning opportunities. Rather than simply completing tasks, students engage in real-time problem-solving and reflection—essential components of both mastery learning and SRL (Andersen & Hvidman, 2020; Bang et al., 2023; Betts, 2019; Kuklick et al., 2023). In this way, digital platforms can offer a scalable, effective approach to supporting deeper, more independent, and longer lasting learning.

The Need for Readily Available Data and Feedback for Teachers

While feedback supports student learning directly, it also plays a critical role in supporting teacher decision-making through formative assessment. Research shows that formative assessment is most effective when it is integrated into daily instruction and used to guide teaching in a continuous feedback loop (Black & Wiliam, 2009; Klute et al., 2017). To use formative assessment effectively, teachers need readily available, actionable data to identify learning gaps and adjust instruction accordingly (Irons & Elkington, 2021). However, the logistics of collecting and analyzing student work in traditional classrooms can be a significant barrier. Teachers often lack the time and capacity to review every student's work in real time, making it difficult to monitor progress, address misconceptions promptly, and tailor instruction effectively (Mendicino et al., 2009). Moreover, without structured mechanisms for interpreting data, even collected information may go unused or underused (Datnow & Hubbard, 2015).

To address these barriers, technology-based platforms are increasingly being used as tools to support formative assessment (Çekiç & Bakla, 2021; See et al., 2022). These platforms can automatically collect student responses, organize results into digestible reports, and surface patterns that might otherwise go unnoticed (Abramovich et al., 2025; Ganimian et al., 2020; Hillmayr et al., 2020; Reinhold et al., 2020; Serin, 2023). By presenting data in clear and timely formats, they can help teachers diagnose misunderstandings, identify knowledge gaps, and adapt instruction more efficiently (Reinhardt et al., 2022).

Technology-based platforms can also facilitate data-driven differentiation by supporting student grouping, providing targeted feedback, and assigning individualized practice (Klute et al., 2017), which may be particularly valuable in classrooms with high student–teacher ratios or limited planning time (Ganimian et al., 2020; Klute et al., 2017; Mendicino et al., 2009). When teachers have efficient access to high-quality data, they are better positioned to close learning gaps and ensure that all students, especially those who are struggling, receive the support they need.

At the same time, technology is not a panacea. Digital platforms do not automatically improve student outcomes; rather, they must be carefully integrated into teachers' existing practices and aligned with instructional goals. Teachers may encounter challenges in interpreting data reports, making adjustments accordingly, or balancing the additional demands of using new systems alongside other responsibilities. In some cases, technology can increase workload if sufficient professional learning and ongoing support are not provided. Thus, while technology-based platforms offer important opportunities to strengthen formative assessment, their effectiveness ultimately depends on how well they are embedded in classroom routines and supported by broader instructional systems.

Use of High-Quality Curricula

Independent practice and formative assessment are more effective when built on a high-quality curriculum that supports both student learning and teacher decision-making. High-quality mathematics curricula emphasize conceptual understanding and procedural fluency through (a) cognitively demanding tasks that support students in making connections between mathematical concepts rather than merely completing disconnected procedures or routines; (b) opportunities to engage deeply with concepts, facts, and procedures; and (c) repeated practice that reinforces skills over time (Agodini et al., 2013; Miller & Courtney, 2023). These curricula often include supports for teachers that enhance their ability to interpret students' thinking processes and guide instruction accordingly (Agodini et al., 2013). They also encourage students to apply strategies they have learned, engage in productive struggle to address misconceptions, and summarize findings as their solution (Miller & Courtney, 2023).

Well-designed math curricula foster students' confidence to independently solve challenging problems, develop math vocabulary and reasoning skills, and persevere with solution processes (Barnett & Bikowski, 2024). Open Educational Resources (OERs) provide an accessible and customizable alternative to structured commercial curricula. OERs are freely available and largely digital curriculum libraries that allow educators to edit, remix, and adapt content to meet their students' needs (Hilton, 2016).

Research consistently shows that students using high-quality OERs perform as well as their peers using traditional materials (Harvey & Bond, 2022; Hilton et al., 2019; Wiley et al., 2012), with both students and educators reporting positive experiences (Cho & Permzadian, 2024; Hilton, 2016; Lourenço et al., 2024). For example, there was no significant difference in math scores between a large sample of elementary students in Washington who used OERs compared with those who used commercially available resources (Hilton et al., 2019). The Illustrative Math curriculum, an OER, has been reported by teachers to foster student engagement. In a survey conducted within a large district, most responding teachers noted that the curriculum motivated persistence, provided appropriate challenge, and encouraged high-level discussion (Cook et al., 2023). The same study also examined student achievement and found that impacts varied by grade level. Based on the Missouri Assessment Program (MAP) state test, results suggested a moderate benefit in grade 3 (N = 1,022 students, 69 classes) and a smaller but significant effect in grades 4–5 (N = 1,994 students, 128 classes), while no clear impact was detected in grades 7–8 (N = 1,841 students, 36 classes). Moreover, OERs can empower educators to consider innovative ways of teaching and learning through the selection of learning content (Lourenço et al., 2024).

Sustained Professional Learning Community

Implementing high-quality curricula and formative assessment practices effectively requires sustained support for teachers. Even the most thoughtfully designed instructional materials and assessment tools can fall short without the professional development needed to help teachers apply them with fidelity. PLCs offer a promising structure for teachers to exchange ideas, codevelop lesson plans, reflect on instructional effectiveness, and collaboratively solve problems with the shared goal of improving student outcomes (Blitz, 2013; DuFour, 2004). Research has shown that participation in PLCs is associated with improved instructional practices and increased student achievement (Darling-Hammond et al., 2017; Lomos et al., 2011). Within PLCs, teachers engage in problem-centered, self-directed learning that exposes them to new practices and allows for reflection while sharing knowledge with one another, ultimately allowing teachers to apply what they learned to their classroom instruction (Hord, 1997; Lave & Wenger, 1991; Wood, 2007).

PLCs have proven especially effective in helping teachers incorporate formative assessment practices (Pape et al., 2012; Supovitz, 2013) and integrate technology into their instruction (Erbilgin & Şahin, 2021). For example, middle school algebra teachers who completed 40 hours of professional development were more effective in designing technology-enhanced lesson plans (Erbilgin & Şahin, 2021). Similarly, teachers who engaged in PLCs and received coaching better understood their students' needs, and their students demonstrated improved learning outcomes in mathematics (Supovitz, 2013). Pairing formative assessment tools with professional learning further improves teachers' knowledge of their students' understanding and students' outcomes (Pape et al., 2012). Beyond contributing to pedagogical and technological gains, PLCs also can foster a sense of belonging and professional identity (Bostancioglu, 2018; Brennan et al., 2018; Carpenter & Munshower, 2020). This is particularly valuable for teachers in rural or isolated schools, who often lack subject-specific colleagues or nearby peer support (Dille & Røkenes, 2021; Karam et al., 2018). In such contexts vPLCs can serve as essential sources of connection and growth.

Even before the COVID-19 pandemic, vPLCs were in use (Beach, 2012), and they have become more widely adopted since the pandemic (Bragg et al., 2021). They have been found to be as effective, or even more effective, than in-person formats when designed well (Blitz, 2013;

Fishman et al., 2013). The virtual formats are more effective and productive when they include relevance to teachers' current work (Bragg et al., 2021; Dille & Røkenes, 2021), ongoing support structures (Morrison & Hughes, 2024), and diverse members with varying levels of expertise (Bragg et al., 2021). Teachers also benefit from engaging in analysis of practice, such as the review and discussion of classroom artifacts or student work (Taylor et al., 2017). A review of 74 peer-reviewed journal articles concluded that vPLCs achieve many of the same goals as in-person PLCs, including increasing content mastery and encouraging self-reflection (Blitz, 2013). Even teachers with lower levels of engagement in vPLCs have reported instructional improvements (Tsiotakis & Jimoyiannis, 2016), while more active participants often experience growth in areas such as differentiated instruction (Wan, 2020).

Rigorous Evidence From Large-Scale Implementations of the Strategies

Independent practice, formative assessment, professional learning, and high-quality curricula offer promising strategies for improving mathematics instruction. To translate the research into practice, it is essential to study how these approaches perform when implemented at scale in diverse, real-world classrooms, which entails challenges in maintaining fidelity to the intended design of interventions while simultaneously adapting them to the heterogeneous needs of students and classrooms. Scaling is further complicated by limitations in teacher capacity, professional development, and instructional time, which can hinder consistent implementation. In addition, variability in access to resources and supports presents a persistent barrier to realizing the full potential of research-based strategies at scale. Educational technology platforms offer promising solutions for addressing these challenges. By delivering adaptive supports, real-time feedback, formative assessments, and data-driven reports, these tools can help improve math outcomes and mitigate learning loss (Abramovich et al., 2025; Ganimian et al., 2020; Hillmayr et al., 2020; Reinhold et al., 2020; Serin, 2023). While many studies report positive effects of educational technology on student achievement (Hillmayr et al., 2020; Saat et al., 2024; Serin, 2023), others have found only small or mixed results (Bielefeldt, 2005; Campuzano et al., 2009; Rutherford et al., 2014), underscoring the need for further research to better understand what works and for whom and to closely examine the implementation and impact of educational technology interventions when they are being used in authentic school settings. This includes identifying implementation barriers, such as lack of access to devices or connectivity, which are more likely to affect disadvantaged students (Andersen & Hvidman, 2020). It also involves examining how factors like curriculum design, teaching practices, technology integration, and school or district infrastructure interact to influence outcomes (Howard & Thompson, 2016; Niederhauser et al., 2018). Rigorous evidence from large-scale implementations can help bridge the gap between research and practice, guiding teachers and administrators in selecting effective, evidence-based programs (Sabelli & Harris, 2015).

To put research into action, large-scale research must consider not only student outcomes but also the contextual variables that influence implementation, including access to technology, instructional alignment, school infrastructure, and teacher capacity (Andersen & Hvidman, 2020; Howard & Thompson, 2016; Niederhauser et al., 2018). Scaling digital interventions helps generate understanding of diverse contexts and the interacting factors between curricular, pedagogical, technological, and individual and organizational considerations (Howard & Thompson, 2016; Niederhauser et al., 2018). In experimental studies, participants who experience the largest intervention effects may be more likely to choose to participate; large-scale interventions yield more generalizable data (Andersen & Hvidman, 2020; Heckman, 1992, 2020; Heckman & Smith, 1995). Findings from scaling are foundational to the successful transfer from research to practice because the aim of scaling interventions is not to merely increase the users of a particular program but to also yield educational gains (Sabelli & Harris, 2015).

The vPLC-Augmented ASSISTments Intervention

The vPLC-augmented ASSISTments intervention integrates two essential elements: the ASSISTments platform, which includes a student-facing interface and teacher-facing tools, and a vPLC designed to enhance instructional practice. The ASSISTments platform (Heffernan & Heffernan, 2014) is rooted in formative assessment, enabling students to complete math problems digitally while providing teachers with immediate data on student proficiency (Heritage & Popham, 2013). Built on this foundation, the vPLC was developed to support teachers in implementing ASSISTments effectively, deepening their instructional strategies and fostering student engagement, motivation, and positive attitudes toward math. This section describes how the integration of the vPLC strengthens the ASSISTments intervention and supports both teaching and learning in diverse educational contexts.

The ASSISTments Platform

The ASSISTments Platform for Students

The ASSISTments platform provides students with opportunities for independent math practice through two major types of assignments: regular assignments and Skill Builders. Regular assignments consist of bundles of prebuilt curriculum problems from OERs, including Illustrative Math and EngageNY. Students work through problems on paper and then enter their answers into ASSISTments, which provides immediate feedback on the correctness of answers (a green check mark for a correct answer). For incorrect responses, students are given multiple opportunities to revise their answers and reattempt the problem. Unlike with other adaptive systems (e.g., IXL) or paper-based assignments, students cannot proceed to the next problem until they have correctly solved the current one. Full credit is awarded for solving the problems independently, while partial credit is given if students use hints or require multiple attempts. Students are expected to complete all problems within a regular assignment to be considered as having completed the assignment. In addition to having regular assignments, ASSISTments offers mastery-oriented problem sets called Skill Builders. Each Skill Builder focuses on a specific math skill and allows students to practice until they achieve a teacher-defined "mastery" threshold of proficiency (e.g., correctly solve three problems in a row). Students who do not reach mastery can reattempt the Skill Builder on another day. Skill Builders provide immediate feedback on the correctness of answers and also offer hints and explanations for incorrect responses, breaking down multiple-part problems and showing students how to solve problems step-by-step to help students improve their answers.

The ASSISTments Platform for Teachers

The ASSISTments platform offers real-time, user-friendly reports that help teachers navigate their classes' and each student's performance on a particular assignment via a grid format. Teachers can leverage the reports to track student progress, challenges, and needs; monitor the knowledge base of the class; and target their subsequent homework review and instruction to support their students. These reports inform teachers about the average percentage correct on each question, questions with lower average accuracy, common wrong answers entered by several students in their class, the skills or standards covered in the assignment, and each student's answer to every question. Color-coded cells provide information on each student's performance in a format that enables teachers to focus on the problems that were difficult for many students. Information about individual student performance can also be used to form instructional groups and address common difficulties. Teachers can share reports with their class by projecting the reports with students' names anonymized. Instructional recommendations are also available for teachers.

Prior Evidence of Efficacy

Prior research has shown that ASSISTments improves student math learning and contributes to long-term academic gains. Two large-scale studies—conducted in Maine and North Carolina—demonstrated the effectiveness of the intervention in different educational contexts (Roschelle et al., 2016; Feng et al., 2025). The yearlong study in Maine, involving 43 schools, showed that 7th grade students who used ASSISTments performed significantly higher on a standardized end-of-year math assessment than those who completed their math work as usual, corresponding with an improvement from the 50th to the 58th percentile (Roschelle et al., 2016). The study also found that greater use of ASSISTments by teachers, along with higher student problem completion rates, was associated with improved achievement. A replication study in North Carolina, involving 66 schools, showed that the effect of ASSISTments was sustained after 1 year of implementation; 7th grade students who used ASSISTments scored higher on the state-administered math assessment at the end of 8th grade compared with students who received business-as-usual math instruction (effect size = 0.10; Feng et al., 2025). ASSISTments has been shown to improve outcomes for lower performing students (Roschelle et al., 2016), those in schools with higher percentages of economically disadvantaged students (Feng et al., 2025), and Hispanic students and students of color (Feng et al., 2025). ASSISTments has also impacted teachers' instruction, leading to instructional practices that are more targeted (Fairman et al., 2015, 2025).

In the Maine and North Carolina implementations, professional development played a key role in supporting teacher use of the platform. Teachers attended 1- or 2-day in-person training events to learn how to use ASSISTments, explore integration strategies, and discuss solutions to specific instructional challenges. Throughout 2 school years, each teacher received three one-on-one coaching visits from a professional learning coach who observed classroom instruction and provided individualized feedback. Additional visits were provided to teachers requiring more support, and coaches remained accessible between sessions via phone, text, or email. While this model offered valuable support, it was labor-intensive, costly, and ultimately not scalable. Moreover, teachers did not have opportunities to build peer networks or engage in collaborative learning with fellow educators, a limitation that highlighted the need for a more sustainable and community-centered approach to professional development.

The vPLC: A Scalable Model for Professional Learning

Building on the prior successes, the current intervention introduced a vPLC as a scalable alternative to in-person coaching models. Developed to support the effective implementation of ASSISTments at scale, particularly in rural and underresourced settings, the vPLC aimed to sustain and enhance the instructional impact of the platform while fostering teacher collaboration, reflection, and professional growth.

vPLC Design and Structure

The vPLC provided teachers with flexible access to high-quality professional learning, enabling them to participate from school or home. The designers of the vPLC prioritized rural educators, who often lack access to local PLCs or peer networks. The virtual format enabled teachers to learn from and share with colleagues across districts and states, facilitating a broader exchange of instructional strategies and experiences. The primary goal of the vPLC was to support the effective use of ASSISTments while cultivating a sense of community among its users. Grounded in the analysis-of-practice model, an evidence-based approach to improving instruction through collaborative reflection (Taylor et al., 2017), the vPLC emphasized interactive, teacher-centered discussions rather than passive workshops. In a responsive, participant-driven format, teachers actively shaped each session by contributing their own practices, pedagogical insights, and instructional approaches. The designers of the vPLC drew on the National Council of Teachers of Mathematics (NCTM) norms (NCTM, 2014) for effective mathematics instruction and adapted them specifically for use with ASSISTments. To support high expectations for all learners, teachers were encouraged to

- assign grade-level problems that align with a learning goal and yield actionable data;
- assign problem sets with a balance of focus on conceptual understanding, procedural skill/fluency, and application;
- support students in identifying appropriate target scores for problem sets based on their current level (e.g., new concept or expected mastery); and
- assign high-leverage problem sets with a variety of problem types and multiple entry points for all learners.

A central theme across sessions was helping teachers transition from traditional paper-based independent practice to the use of ASSISTments for classwork and homework. The vPLC emphasized how to leverage real-time data to improve student engagement and learning while easing teachers' workload. Feedback collected through teacher surveys informed continuous improvements to the vPLC structure. Improvements included integrating community norms, tone-setting activities, icebreakers, and what the vPLCs call "Stories From the Field" to highlight teacher expertise and included using shared reports across sessions to maintain continuity and build depth.

vPLC Content and Facilitation

The vPLC included both synchronous and asynchronous components. Teachers participated in eight 75-minute virtual sessions, each preceded by thought-provoking asynchronous activities delivered via Slack. Two former middle school teachers experienced in using ASSISTments facilitated these sessions using a facilitation guide grounded in best practices for professional learning.

Each session focused on a key instructional concept (see Table 1; further details are included in Appendix A) and followed a consistent structure. Sessions opened with a welcome, an icebreaker activity, and a reminder of the group norms and goals. This was followed by a Story From the Field in which a participating teacher shared a slide featuring a quote and a discussion question rooted in a real instructional experience. The storyteller elaborated on the context, and other teachers responded with insights, related experiences, and suggestions.

Next, facilitators introduced the session's core concept, demonstrated a relevant ASSISTments feature, or presented an external resource (e.g., NCTM guidance, articles and books discussing best teaching strategies). Teachers then broke into small groups (two or three participants) to discuss a prompt in depth, referencing their own classrooms, assignments, and student data. Individual groups shared takeaways in a full-group discussion while facilitators synthesized and reinforced key ideas. Sessions concluded with a "Teachers' Lounge" segment for informal peer-to-peer questions and a reflection activity in which teachers summarized their key takeaways using digital sticky notes. To support new ASSISTments users, additional resources were provided, including an individual virtual onboarding session and guidance on interpreting platform reports. Facilitators provided one-on-one support for teachers with low usage or challenges integrating ASSISTments to ensure continued engagement.

Table 1. Content of the vPLCs

vPLC Topic	Learning content
Session 1: Establishing High Expectations for All Learners	• Routines and structures that create a supportive environment and help students foster a sense of belonging • NCTM guidelines for teaching mathematics with high expectations—breakout discussion • Upholding high expectations while assigning a problem set—practice within ASSISTments
Session 2: Assignment Report Overview	• Assignment report video tour • Your assignment report analysis • Actionable next steps for instruction—breakout discussion
Session 3: Common Wrong Answer and Student Details Report	• Assignment report overview and highlight video • Analyzing common wrong answers and identifying alternate student conceptions • Selecting individual students or common problems for reteaching—breakout discussion
Session 4: Creating a Collaborative Learning Environment	• Assignment report highlights—Common Wrong Answer, Reviewing Reports with Students, Student Assignment Report (student view) • Routines and structures for reviewing reports with the class • Opening comments or questions to promote a collaborative learning culture—breakout discussion
Session 5: ASSISTments Data to Inform and Differentiate Instruction	• What are Skill Builders, and why use them? • Interpreting the Skill Builders Report • What are Score Chips? • Grade-specific instructional recommendations and lesson plans • What data indicate a need for differentiation?—breakout discussion

vPLC Topic	Learning content
Session 6: Constructing Effective Individual Feedback	• Student Details Report (teacher view) • Using Student Details Reports to make the most of one-on-one student conversation or whole-class discussion • Using Student Details Reports to individualize instruction • Data that indicate a need for individualized feedback and example feedback—breakout discussion
Session 7: Orchestrating Class Discussions Around Open Response Questions	• Scoring open response questions • Quick comments for easy scoring • Five process standards for mathematics defined by NCTM • Five practices for orchestrating productive mathematical discussions • Example problem: How would you strategically sequence and share student work leveraging ASSISTments open responses?—breakout discussion • Cost–benefit analysis: Reviewing student-generated solutions versus teacher-constructed explanations
Session 8: Student Engagement and Motivation	• Three components of motivation: autonomy, competence, and relatedness • How may ASSISTments support the three components of motivation? • Strategies to help students avoid spring burnout; ASSISTments routines • Five ways to motivate students to learn math; and ASSISTments routines • Select strategies from the three articles that you plan to use to engage and motivate your students while leveraging ASSISTments. How will you use this strategy, and how does this support student engagement and motivation?—breakout discussion
Session 9: (Optional) Celebrating Our ASSISTments Journey	• Share and celebrate: Most significant takeaways from vPLC learning and ASSISTments implementation
Session 10: (Optional) Teacher Discussions	• Review of instructional recommendations • Successful formative assessment routines • Differentiation while leveraging ASSISTments; resources

vPLC and the Formative Assessment Cycle

The vPLC content was intentionally aligned with the 4-step formative assessment process (Heritage & Popham, 2013) that is integrated throughout the ASSISTments platform:

1. **Create Assignments:** In the first step, teachers select or design problem sets aligned with grade-level standards. This includes using OERs, custom problem sets, or Skill Builders that target specific skills. This foundational step was covered in the first vPLC session.
2. **Assist Students Through Immediate Feedback:** Students complete assignments independently in ASSISTments while receiving immediate feedback, hints, and explanations. Throughout all vPLC sessions, facilitators encouraged teachers to normalize mistakes and promote a growth mindset, with a particular focus on motivation and engagement in session 8.
3. **Assess Class Performance:** Teachers review performance reports to identify student needs and inform future instruction. Sessions 2 through 6 explored the use of ASSISTments reports in depth, with each session highlighting different report features and data-usage strategies to help teachers build their instructional toolkit over time.
4. **Analyze Answers Together:** Teachers project anonymized reports for whole-class review and guide discussions on common misconceptions and problem-solving strategies. This collaborative review process was the focus of session 7.

The ultimate goal of progressing through these steps is to improve student math achievement. The vPLC aimed to help teachers internalize and implement this cycle by embedding it across session content and instructional planning.

Methods

Guided by the vPLC-augmented ASSISTments intervention logic model (Figure 1), WestEd conducted a quasi-experimental design (QED) study during the 2022–23 and 2023–24 school years. The study seeks to address the following research questions:

1. Do participating schools implement vPLC-augmented ASSISTments as intended by the developer? How much usage occurs? To what extent is each feature used?
2. What is the effect of vPLC-augmented ASSISTments on the math achievement of middle school students (grades 6–8) compared with the math achievement of the middle school students in the comparison group?

3. Do the effects of vPLC-augmented ASSISTments vary for students with different prior achievement and for students with other policy-relevant characteristics (such as rural versus nonrural)?
4. What effects do implementation variation have on student learning?
5. How is the implementation of the vPLC-augmented ASSISTments intervention associated with teachers' use of data to inform and adjust instructional practices? How is teachers' use of data associated with the effects of the intervention on student learning?
6. How is the use of the ASSISTments platform by individual students and at the class level associated with student learning?
7. What are the factors that hinder or facilitate implementation?

Figure 1. vPLC-Augmented ASSISTments Logic Model

<table>
<tr><th>Key intervention components</th><th>Activities/change in practice associated with key components</th><th>Mediators</th><th>Outcomes</th></tr>
<tr><td>Teacher vPLC
Synchronous new user training on how to use ASSISTments
Synchronous ongoing virtual meetings for sharing of learning and challenges
Asynchronous online community for ongoing exchange of ideas and problem-solving</td><td>Teachers participate in new user training to learn how to use the product.
Teachers gather to share things learned and challenges and to dive into topics related to the effective use of ASSISTments.</td><td rowspan="2">Teacher classroom practices change:
More efficient feedback on and monitoring of student challenges and progress
Review and discussion of assignments in a more targeted way, driven by report data
More use of data to inform instruction and assignment decisions</td><td rowspan="4">Improved year-end mathematics achievement</td></tr>
<tr><td>Prebuilt Content for Math Work Assignment
OER curriculum problems from EngageNY/Eureka or Illustrative Math
Mastery-based Skill Builders with support and on-demand hints</td><td>Teachers create assignments in ASSISTments by choosing OER curriculum problems and/or Skill Builders.</td></tr>
<tr><td>Support of Data-Driven Adaptation in Instruction
Data on student performance on all problems assigned in platform by the teacher
Instructional recommendations for teachers in response to student data</td><td>Teachers open reports in ASSISTments and analyze how each student performed.
Teachers review reports anonymously with the whole class and discuss misconceptions demonstrated by the reports.
Teachers refer to the instructional recommendations.</td><td>Classroom climate change:
Higher student engagement during assignment review
More acceptance of mistakes as part of learning at a higher level</td></tr>
<tr><td>Immediate Support for Students
Immediate feedback while working on problems
Mastery-based Skill Builders with on-demand hints</td><td>Students work on assignments in ASSISTments.
Students receive immediate feedback on the correctness of their responses.</td><td></td></tr>
</table>

Study Design

The study was initially designed as a randomized controlled trial (RCT), with participating schools assigned at random to either a treatment condition (implementation of the vPLC-augmented ASSISTments intervention) or a control condition (business-as-usual math instruction). During the 2020–21 and 2021–22 school years, however, recruitment proved more challenging than anticipated, particularly as schools continued to navigate the disruptions of the COVID-19 pandemic. In response, the research team adjusted the design to a QED with a matched comparison group to ensure meaningful participation and to maintain the rigor and relevance of the study under the circumstances. The study was structured to meet What Works Clearinghouse (WWC) standards with reservations (WWC, 2022).

In the treatment condition, teachers implemented the vPLC-augmented ASSISTments intervention, which included four core components (see Figure 1). First, to support onboarding and instructional consistency, teachers participated in a new user training and joined the vPLC. They were expected to attend at least seven of eight synchronous vPLC sessions held between September and February and to complete at least four of eight asynchronous activities on Slack. Second, teachers were asked to assign prebuilt content through the ASSISTments platform—specifically, independent practice assignments at least three times per week for 17 weeks, using a combination of regular assignments and Skill Builders. These could be assigned as classwork or homework. Third, to promote data-driven instruction, teachers were expected to review student performance reports for at least half of their assignments and use the data to guide instructional adjustments, including sharing results with students. Finally, students were expected to complete at least two thirds of the problems assigned to them, with the goal of having a minimum of 75 percent of students in each class meet this engagement threshold.

For the comparison condition, a virtual comparison group (VCG) was constructed by NWEA using students' pretest scores on the NWEA MAP Growth assessment for mathematics (NWEA, 2019), which was administered to treatment students at baseline in the fall. Each treatment student was matched with up to 51 students drawn from NWEA's national database. Matching criteria included school locale, the percentage of students eligible for free or reduced-price lunch at the school level, test administration dates, grade level, and pretest scores. The average performance of the matched students was then used to represent the outcome for the virtual comparison student for the corresponding treatment student. This approach allowed for a robust counterfactual group that was demographically and academically comparable, despite the absence of random assignment.

Settings and Participants

The recruitment team prioritized public school math teachers in rural districts that had adopted OER mathematics curricula. Recruitment focused on schools located in areas classified by the National Center for Education Statistics (NCES) as Town–Distant (32), Town–Remote (33), Rural–Fringe (41), Rural–Distant (42), or Rural–Remote (43). Eligible participants included 6th-, 7th-, and 8th grade general education math teachers whose students had access to technology allowing them to complete internet-based classwork and homework. Recruitment took place during the winter, spring, and summer prior to each study year and involved direct outreach to teachers, school and district administrators, and state-level education staff. The ASSISTments Foundation also promoted the study through its website. Interested teachers completed an online interest form and participated in a virtual meeting with the research team to review study expectations and ask questions. Teachers who enrolled in the study completed a consent form, and their schools or districts signed a memorandum of understanding.

The final treatment sample included middle school math teachers from 36 public schools across 24 U.S. states. Participating schools represented diverse demographic and geographic contexts: There were 18 schools located in rural areas, and 23 were eligible for Title I funding. Many schools had experienced recent declines in math performance, and participating teachers expressed interest in using technology to support learning recovery.

The treatment group involved 59 teachers and their 2,855 students in 6th through 8th grades (approximately 13% were in 6th grade, 74% were in 7th grade, and 12% were in 8th grade). About 60 percent of students were White, 21 percent were Hispanic, 10 percent were African American, and 9 percent belonged to other racial or ethnic groups. More than half of the students (55%) were eligible for free or reduced-price lunch. Fifty percent of the students were in rural areas.

When the VCG was constructed, each virtual comparison student was assigned a matching level indicating the degree that the matching criteria had to be from the most stringent set of values. This "comparison criteria level" ranged from 0 to 8, with smaller values indicating a closer match. Table 2 summarizes the number and percentage of virtual comparison students at each level in the VCG. Overall, approximately 89 percent of VCG students were within comparison criteria Levels 0–2, meaning that the baseline scores of the matched students differed from those of the treatment students by no more than 2 points. These matched students also came from the schools with a similar percentage of students eligible for free or reduced-price lunch (within 5%), came from the same school locale, and had test administration dates (pretest or posttest) within 7 days of the corresponding treatment student.

Table 2. The Number of VCGs by Comparison Criteria Level

Comparison criteria level	Baseline score	School % FRL	Days between tests	School locale code	Number of students	Percentage	Cumulative percentage
0	+/-0	+/-5	+/-7	Exact Match	1,578	55.27	55.27
1	+/-1				728	25.50	80.77
2	+/-2				235	8.23	89.00
3			+/-10		67	2.35	91.35
4		+/-10			129	4.52	95.87
5		+/-15			39	1.37	97.23
6	+/-3				28	0.98	98.21
7			+/-18		42	1.47	99.68
8	+/-4				9	0.32	100.00
Total					**2,855**	**100**	**100**

***Note*. Blank cells inherit values from the cell above them. FRL = eligible for free or reduced-price lunch.**

Baseline Equivalence

The baseline equivalence test on the pretest revealed that the average mean of VCGs was very close to the treatment group (effect size = -0.03), implying that the matching algorithm worked as expected (Table 3).

Table 3. Baseline Equivalence Test on the Pretest

	Tx	*n*	VCG	*n*	Diff	SE	*p*	Effect size	WWC
Pretest	216.60	2,855	217.01	2,855	-0.41	1.140	0.720	-0.03	satisfies the baseline equivalence requirement [0 < = absolute ES < = 0.05]

***Note*. Tx = Treatment; Diff = Difference; SE = Standard Error. Effect size was calculated based on the pooled standard deviation.**

Measures

To evaluate the implementation and impact of the vPLC-augmented ASSISTments intervention, the study employed a structured procedure and a comprehensive set of measures collected from participating teachers and students over the course of the school year. Teachers were asked to attend a study orientation at the beginning of the year; administer the NWEA MAP Growth assessment to students in both the fall and spring; and complete multiple data collection activities, including pre- and post-intervention surveys, four instructional logs, interviews, and classroom observations. Interviews and observations were conducted with a selected subgroup of participants, while all teachers were expected to complete the other measures. These expectations were communicated clearly during recruitment meetings and on interest and consent forms, and they were reiterated during the orientation session. Throughout the study, the research team maintained regular communication with teachers to encourage participation, provide reminders about upcoming activities, address challenges, and answer questions, ensuring consistent and reliable data collection across both cohorts.

Outcome Measure: MAP Growth Math Assessment

Student mathematics learning—the student outcome of interest—was measured using the online MAP Growth math assessment provided by NWEA, which has demonstrated the desired psychometric properties (NWEA, 2019). Each assessment typically required 45 to 60 minutes for students to complete. For Cohort 1, treatment students completed the assessment in fall 2022 (baseline) and spring 2023; the assessment was administered to the Cohort 2 treatment students in fall 2023 (baseline) and spring 2024. Following test administrations and matching procedures, NWEA provided the study team with a data set containing score information for both the treatment students and the VCG. The derived scale scores (Rasch Unit, or RIT, scores), which are based on the Rasch item response theory model, served as the primary outcome measure for evaluating the impact of ASSISTments on students' mathematics learning.

Implementation Measures

vPLC Participation

Facilitators of the vPLC sessions tracked teacher attendance and assignment completion to monitor engagement and identify participants who might benefit from additional support. These participation data were also used by researchers to assess implementation fidelity, providing insight into the extent to which teachers adhered to the expected level of involvement in the vPLC component of the intervention.

System Log Data

ASSISTments system log data that tracked assignments made by teachers, student problem-solving actions, and teacher use of reports were collected continuously during the study and served as the primary data source for determining treatment implementation fidelity. In addition, these data were used to calculate dosage for each student.

Teacher Logs and Surveys

Teacher instructional logs and surveys were used to collect contextual information and to document instructional practices across the study period. Instruments included a pre-intervention survey, a post-intervention survey, and four rounds of instructional logs. The pre-intervention survey gathered information on teachers' backgrounds (11 items), class context (9 items), and baseline instructional practices (21 items). The post-intervention survey included similar class context and instructional practice categories (8 and 23 items, respectively) and added items related to teachers' experiences with ASSISTments and the vPLC (19 items). Instructional logs were administered in four rounds—twice before and twice after the winter break—with teachers completing entries for 5 consecutive instructional days during each round. Each log contained 34 items on instructional decisions and 17 items related to the use of ASSISTments and the vPLC. Item formats included matrix questions, multiple choice questions, check-all-that-apply items, and open-ended responses, with survey logic used to tailor items to each teacher's context. Teachers accessed the instruments through personalized Qualtrics links, which allowed content to be customized based on the specific curriculum used in their classrooms.

Teacher Interviews

To better understand teachers' experiences with implementing the ASSISTments intervention, researchers conducted individual, semistructured interviews via video call at the end of each study year. These 60-minute interviews explored both supports and challenges related to implementation, with a focus on how teachers used ASSISTments for independent practice, including how they selected problems to assign, differentiated instruction, conducted problem reviews, and used student data and reports. Teachers were also asked to reflect on changes in their instructional practices compared to prior years, their engagement with the 4-step formative assessment process of ASSISTments, their participation in the vPLC, their use of other educational technology tools, their school-based professional supports, and their perceptions of students' experiences with the platform.

Interviews for Cohort 1 occurred between May and early June 2023; for Cohort 2, interviews were conducted between late April and mid-June 2024. All 16 teachers in Cohort 1 were invited and interviewed. For Cohort 2, a representative sample of 17 teachers was selected based on several criteria, including the grade level covered by the school, the number of participating teachers at their school, vPLC attendance, and ASSISTments usage (e.g., system data on the average number of assignments per week and log data on assignment type, report usage, and data-driven review practices). Researchers also considered the frequency of teachers' use of other educational technology programs for independent practice. The selected sample reflected the broader Cohort 2 population across key characteristics, ensuring that diverse perspectives on implementation were captured.

Classroom Observations

Classroom observations were conducted to capture a snapshot of ASSISTments implementation in real time, identify supports and challenges, and document how teachers and students interacted with the platform during instruction. During each visit, researchers took detailed field notes on teacher and student behaviors, their use of ASSISTments, and indicators of student engagement. Immediately following the observations, researchers conducted brief semistructured interviews with teachers to contextualize what was observed. These 30-minute interviews included questions about the degree to which the observed class period was typical; variations in ASSISTments use across different class sections or grade levels; and teachers' reflections on their use of formative assessment, real-time instructional adjustments, use of data, and participation in the vPLC.

Teachers were selected for observation based on several factors, including their frequency of ASSISTments use, level of participation in the vPLC, geographic location, and logistical feasibility (e.g., proximity to researchers and other study participants). The sample was selected to ensure variation in school locale, region, number of participating teachers per site, and school type. In Cohort 1, researchers observed the classrooms of ten 7th grade teachers at eight schools (five public, two charter, and one private school; three rural schools) between late March and early May 2023. In Cohort 2, 11 teachers were observed at six schools (five public and one private school; two rural schools) between late February and late March 2024. The observed teachers included three 6th grade teachers, five 7th grade teachers, two 8th grade teachers, and one teacher who taught both 7th and 8th grades.

Student Demographics and School Context

To describe the student sample and broader school context, researchers collected demographic data from the NCES database. This included information on school locale classifications; Title I eligibility; the racial and ethnic composition of the student body; and the percentage of students receiving free or reduced-price lunch, which served as a proxy for socioeconomic status. To enable subgroup analyses, researchers also requested individual-level student data from districts, including gender, race/ethnicity, English Language Learner (ELL) status, and individualized education program (IEP) status.

To further contextualize school environments, researchers conducted semistructured interviews with principals at selected study schools. These 30-minute video conference interviews focused on school and community characteristics, student performance in math, use of standardized assessments and other data systems, curriculum adoption, student access to technology, and principals' awareness of teachers' use of ASSISTments and participation in vPLCs. Principals were selected to reflect variation in geographic region, school locale (urban and rural), and the number of teachers at the school participating in the study. In Cohort 1, researchers interviewed seven principals from six states (five public, one charter, one private school; four rural schools) between late March and May 2023. In Cohort 2, 10 principals (from 6 public, 2 charter, and 2 private schools; four rural schools) from nine states were interviewed between October and early November 2023. Researchers ensured that no principal was interviewed in both years. Participating schools varied in the number of study-enrolled teachers, ranging from one to three per site.

Data Analysis Methods

Quantitative Analysis (Research Questions 1–6)

Implementation Fidelity

For Research Question 1 (RQ1), a fidelity matrix was constructed to track fidelity of implementation across the 2022–23 (Cohort 1) and 2023–24 (Cohort 2) school years. The fidelity matrix specifies measurable indicators aligned with each key component of the vPLC-augmented ASSISTments intervention as outlined in the logic model (Figure 1):

1. **Teacher vPLC.** Fidelity of this key component was assessed at the teacher level using three indicators: (a) teachers' attendance at new-user training, (b) their participation in synchronous vPLC meetings, and (c) their completion of asynchronous assignments (see Appendix B, Table B1).
2. **Prebuilt Content for Math Work Assignment.** The fidelity of teachers' use of prebuilt content, including regular assignments and Skill Builders, in ASSISTments was measured at the classroom level with two indicators: (a) the number of weeks in which assignments

were made in ASSISTments and (b) the average number of assignments per week (see Appendix B, Table B2).

3. **Support of Data-Driven Adaptation in Instruction.** Teachers' engagement with ASSISTments reports was used as a proxy for their use of data to inform instruction. Fidelity for this key component was measured by the frequency with which teachers opened and reviewed ASSISTments reports for the assignments they had made to the classes (see Appendix B, Table B3).
4. **Immediate Support for Students.** Student assignment problem completion rate was used as a proxy indicator for the level of immediate support students received from ASSISTments. Fidelity for this key component was measured by the proportion of students in each class who completed at least 68 percent (about two thirds) of their assigned problems (see Appendix B, Table B4).

For each indicator, the matrix establishes the thresholds that define adequate implementation for the key component at the unit of measurement (e.g., teacher level or class level). These unit-level thresholds are then aggregated across the study sample to determine program-level fidelity criteria. Table 4 provides a summary of the fidelity of implementation indicators and thresholds for each key component.

Table 4. Fidelity of Implementation Matrix

Intervention key component	Implementation measure (measurable indicators representing each component)	Component-level threshold for adequate implementation for the unit that is the basis for the sample level	Evaluator's criteria for "Implemented With Fidelity" at sample level
1. Teacher vPLC	Three indicators: • new user training • ongoing virtual meetings • asynchronous participation in online community activities	Teachers attended the new user training if applicable, at least 5 vPLC meetings, and at least 50% of online assignments.	75% of teachers met adequate implementation threshold for the component

Intervention key component	Implementation measure (measurable indicators representing each component)	Component-level threshold for adequate implementation for the unit that is the basis for the sample level	Evaluator's criteria for "Implemented With Fidelity" at sample level
2. Prebuilt Content for Math Work Assignment	Two indicators: • Number of weeks teachers assign independent practice over the school year via ASSISTments • Number of independent practice assignments teachers assign via ASSISTments each week	Teachers assigned at least one regular assignment on average for at least 17 weeks for a class.	75% of classes met adequate implementation threshold for the component
3. Support of Data-Driven Adaptation in Instruction	One indicator: • Percentage of opened reports by teachers	Teachers opened reports for at least 50% of the regular assignments for the class.	75% of classes met adequate implementation threshold for the component
4. Immediate Support for Students	One indicator: • Percentage of problems students solved	75% of students in the class completed at least 68% of problems assigned to them from the regular assignments.	75% of classes met adequate implementation threshold for the component

Impact Analysis

Based on the original RCT design, the unit of random assignment was the teacher. To estimate the treatment impact (for RQ2), a two-level hierarchical linear model (students nested within teachers) would have been used. However, with the current QED design, matching was done at the student level, which complicated the impact analysis: The intervention was still implemented at the teacher level, but there was no teacher level for the VCG. Therefore, a hierarchical linear model based on a partially nested RCT design was adopted (Lohr et al., 2014). This type of model was initially designed for RCTs in which treatment students receive intervention services in groups (teachers or classrooms), but this grouping does not occur for control students. The partially nested RCT design can also be applied to QEDs, especially the matched comparison group design (Lohr et al., 2014).

Since only treatment students were nested in teachers (referred to as intervention clusters, or ICs), the model allows additional variation at the cluster/teacher level for the treatment group. In other words, instead of treating the coefficient associated with the impact estimate (typically represented by the treatment indicator, 0 or 1) as fixed, it is treated as a random effect with an error term in the model. The model takes the following form:

Level 1 Model: $Y = \beta_0 + \beta_1 (treat) + r$

Level 2 Model: $\beta_0 = \gamma_{00}$

$\beta_1 = \gamma_{10} + \mu_1$

Mixed Model: $Y = \gamma_{00} + \gamma_{10} (treat) + \mu_1 (treat) + r$

In these equations, *treat* is coded 1 = treatment and 0 = control, γ_{00} is the expected value of the control condition, γ_{10} is the expected value of the treatment effect, μ_1 is the error term associated with treatment clusters, and *r* is the residual error. The pretest scores were included as a covariate to adjust for the baseline difference in the model. The research team followed the steps in Lohr et al. (2014) to prepare the data set and specify the model.

For RQ3, the same partially nested model was used, but the analyses were based on two distinct subsamples: the low-performing students and students in rural schools. Low-performing students were identified based on treatment students' percentile rank on the pretest, with those scoring below 50th percentile classified as low performing. Students' rural status was determined using school locale code established by NCES.

For RQ4, a similar partially nested model was employed. However, the analyses compared three groups: (a) treatment students taught by the teachers, or in the classes, that met the threshold for adequate implementation; (b) treatment students taught by the teachers, or in the classes, that did not meet the threshold; and (c) the VCG. The analysis was conducted separately by each of the four key components of the intervention:

- the teacher's participation in the professional development training and the subsequent vPLC: Those teachers who participated in the new user training and attended more vPLC sessions were considered to have met adequate implementation.
- the teacher's use of prebuilt content in ASSISTments by making regular assignments to the class by the number of weeks and the number of problems in that week: Those classes whose teachers assigned at least one problem set for at least 17 weeks and that had overall average weekly assignments of three or above were considered to have met adequate implementation.
- the teacher's use of data provided by ASSISTments to support instructions: Those classes whose teachers opened at least half of the regular assignments were considered to have met adequate implementation for the class.
- students receiving immediate supports during problem-solving: Those classes with 75 percent of students completing at least 68 percent of problems assigned to them from regular assignments were considered to have met adequate implementation for the class.

Except for the first key component, in which the analysis was conducted at the teacher level (the cluster unit), the analysis of implementation for the remaining key components was conducted at the class level.

Analyses of Teacher Surveys and Instructional Logs

To address RQ5, the first step was to calculate two implementation-related variables based on the fidelity matrix (Table 4): participation in vPLC and the use of ASSISTments. Participation in vPLC was determined by summing the second and third indicators of the first key component (i.e., ongoing virtual meetings and asynchronous participation in online community activities). The resulting variable ranges from 1 to 4. Similarly, the use of ASSISTments was obtained by summing all three indicators in the second and third key components of the fidelity matrix. The resulting variable ranges from 1 to 6.

Second, teacher post-intervention survey and log data were combined and summarized to examine how participation in the vPLC and the use of ASSISTments influenced teachers' self-reported use of data to inform instruction. All survey and log items related to reviewing and using data reports were identified. Nineteen items were then grouped into two composite variables, each capturing a distinct aspect of teachers' instructional practices.

- Composite 1: Use data to guide in-class review of student math work from class practice or homework. The composite included six items reflecting teachers' use of data (from both ASSISTments and non-ASSISTments sources) to guide their review of student math work with the whole class. Greater weight was given to the frequency with which teachers projected reports to the class because this represented opportunities for students to engage in rich, data-informed classroom discussion. Final composite scores ranged from 0 to 2. Higher scores indicated either (a) the teacher frequently shared reports with students or (b) the teacher frequently used reports to make decisions regarding in-class problem review, including deciding which problems to review with the class or what math concepts or skills to review, and the teacher's frequency of projecting reports to students was medium.
- Composite 2: Use data to inform adjustment of classroom instruction. This composite included 13 items consolidated into four subdomains that captured teachers' use of data to inform adjustment of their classroom instruction: (a) the frequency of instruction changes based on the review of ASSISTments data, (b) the frequency of instruction changes based on the review of non-ASSISTments data, (c) the teacher's retrospective view of using data to inform instruction, and (d) the teacher's retrospective view of using data to identify students for individual support. Descriptive analysis was used to determine the thresholds for high versus low frequency within each subdomain, with high receiving a score of 1 and low receiving a score of 0. Composite scores ranged from 0 to 4 based on the sum of the subdomain scores.

The correlational analysis was then conducted to examine the associations between vPLC participation, ASSISTments use, and the two composite scores. Subsequently, a conventional two-level regression model (students nested within teachers) was used to test how each of two aspects of teachers' use of data was associated with the student learning outcome, controlling for a set of student-level covariates (the pretest score, gender, ethnicity, and locale).

Analyses of Other Usage Data

Similarly, for RQ6, conventional one-level and two-level regression models were used to study the association between student usage data and learning outcome, controlling for the same set of student-level covariates described previously. The one-level model was used primarily to estimate the effect size of the association (i.e., partial eta squared) for interpretation (Richardson, 2011). Given that the majority of variance in the outcome was explained at the student level, it was appropriate to use the one-level model. A three-level model (adding class as the Level 2 clusters) was used for class-level usage data.

Qualitative Analysis (Research Questions 7–8)

Interviews were audio-recorded and transcribed by a third-party service. Initial analysis was informed by researchers' post-interview reflections and a team debriefing meeting. Four coders conducted the coding, beginning with data reduction through thematic analysis (Onwuegbuzie & Teddlie, 2003). Interview transcripts and observation records were coded using theoretically derived categories from the literature. The team also engaged in open, inductive coding (i.e., grounded theory) to iteratively develop codes that were theory driven and responsive to the data (Clarke & Braun, 2017). Through constant comparison (Corbin & Strauss, 2008), coded excerpts were reviewed, grouped, and categorized to refine emerging themes. Coders met regularly to clarify theory-based codes, establish data-driven codes, and resolve discrepancies. Emergent codes were then systematically applied across the data set.

Results

Implementation Fidelity (Research Question 1)

Based on the fidelity matrix and the defined threshold for adequate implementation, the program met the fidelity thresholds for Key Components 1, 2, and 3 but not for Key Component 4 (Table 5). For details of fidelity by cohort, see Appendix C.

Table 5. Fidelity of Implementation Results for Study (Cohorts 1 and 2 Combined)

Intervention component	Sample size at the sample level (# of schools, districts, etc.)	Component-level threshold for adequate implementation for the unit that is the basis for the sample-level	Evaluator's criteria for "implemented with fidelity" at sample level	Component-level fidelity score for the entire sample	Implemented with fidelity
1. Teacher vPLC	62 teachers	Teachers attended the new user training if applicable, at least five vPLC meetings, and at least 50% of online assignments	75% of teachers met adequate implementation threshold for the component	87% (44/62) met threshold	Yes
2. Prebuilt Content for Math Work Assignment	168 classes	Teachers assigned at least one regular assignment on average for at least 17 weeks for a class	75% of classes met the adequate implementation threshold for the component	76% (128/168) met threshold	Yes
3. Support of Data-Driven Adaptation in Instruction	168 classes	Teachers opened reports for at least half of the regular assignments for the class	75% of classes met the adequate implementation threshold for the component	92% (154/168) met threshold	Yes

Intervention component	Sample size at the sample level (# of schools, districts, etc.)	Component-level threshold for adequate implementation for the unit that is the basis for the sample-level	Evaluator's criteria for "implemented with fidelity" at sample level	Component-level fidelity score for the entire sample	Implemented with fidelity
4. Immediate Support for Students	168 classes	75% of students in the class completed at least 68% of problems from the regular assignments	75% of classes met the adequate implementation threshold for the component	62% (108/168) met threshold	No

Key Component 1: Teacher vPLC

Implementation fidelity of the teacher vPLC component was assessed at the teacher level using participation data, including teachers' attendance at a new-user training, synchronous vPLC meetings, and completion of asynchronous assignments (see Appendix B, Table B1). For Cohort 1, 15 of 16 teachers fulfilled the requirement for new-user training, 14 attended at least seven of the eight synchronous vPLC sessions, and 14 completed at least half of the asynchronous assignments. Based on the combined indicator scores, 12 of the 16 teachers (75%) met the threshold for teacher-level fidelity and the program met the benchmark for Key Component 1. For Cohort 2, 44 of 46 teachers either attended or were exempt from new-user training, 33 attended at least seven of the eight synchronous vPLC meetings, and 37 completed at least half of the asynchronous assignments. This level of participation also met the benchmark for Key Component 1. Overall, across both cohorts, 44 of the 62 teachers (87%) achieved the fidelity threshold for the Teacher vPLC component, indicating that the program met the threshold for Key Component 1.

Key Component 2: Prebuilt Content for Math Work Assignment

According to the system usage data, 35 of the 39 classes in Cohort 1 had at least one ASSISTments regular assignment for 17 or more weeks. Twenty-five classes received a moderate number of assignments per week (one or two), while 15 classes received a high number of assignments per week (three or more). Overall, 92 percent of classes met the math assignment unit threshold, indicating that the program met the benchmark for Key Component 2.

In Cohort 2, 87 of 129 classes had at least one regular assignment for 17 or more weeks. Teachers assigned 99 classes a moderate number of assignments per week (one or two), and 30 classes had a high number of assignments (three or more). In this cohort, only 71 percent of classes met the math assignment unit threshold, indicating that the program with this cohort did not meet the fidelity benchmark for Key Component 2. Across both cohorts, 128 of 168 (76%) classes met the math assignment unit threshold, demonstrating that the program achieved the fidelity threshold for Key Component 2.

Key Component 3: Support of Data-Driven Adaptation in Instruction

In the 2022–23 school year, teachers reviewed reports on at least 50 percent of assignments for 35 of 39 classes using ASSISTments. With 90 percent of classes meeting the unit threshold, the program satisfies the fidelity threshold for Key Component 3. In the 2023–24 school year, teachers reviewed reports for at least 50 percent of assignments in 119 of 129 classes, with 92 percent meeting the unit threshold. Across both cohorts, 154 of 168 (92%) classes met the threshold, indicating that the program consistently met the fidelity threshold for Key Component 3.

Key Component 4: Immediate Support for Students

In the 2022–23 school year, 28 of 39 classes (72%) met the threshold for Key Component 4, which was insufficient for the program to meet the fidelity benchmark for this component. In the 2023–24 school year, 80 of 129 classes (62%) met the threshold, again falling short of the benchmark. Across both cohorts, 108 of 168 classes (64%) met the problem-completion threshold, indicating that the program did not achieve the fidelity threshold for Key Component 4.

Impact of vPLC-Augmented ASSISTments: Overall and by Subgroup (Research Questions 2–3)

The impact analysis results indicate that the difference in the posttest scores between the treatment group and VCG was not statistically significant at the 0.05 level ($p = 0.172$, effect size = 0.04). However, treatment students who scored below the 50th percentile on the pretest demonstrated significantly greater improvement than their VCG counterparts ($p = 0.020$, effect size = 0.10). Comparable results were found when the analysis was restricted to students in rural areas (see Table 6).

Table 6. Impact of ASSISTments With vPLC, Overall and by Subgroup

	Tx (adjusted mean)	VCG (adjusted mean)	Diff	SE	*P*	ES	Tx (n)	Tx (SD)	VCG (*n*)	VCG (SD)
Posttest (all sample)	223.95	223.28	0.67	0.488	0.172	0.04	2,855	17.277	2,855	15.048
Posttest (low performing)	214.38	213.18	1.20*	0.500	0.020*	0.10*	1,626	13.230	1,626	9.670
Posttest (rural only)	225.53	224.88	0.65	0.667	0.339	0.04	1423	16.438	1423	14.133
Posttest (low performing in rural)	215.51	214.26	1.26*	0.607	0.049*	0.11*	733	12.964	733	9.217

*significant at the 0.05 level

Note. Effect size was calculated based on the pooled standard deviation.

Impact by the Level of Implementation of Four Key Components (Research Question 4)

As shown in Tables 7–10, the results indicate that while the students in the meeting adequate implementation group tended to score higher than the VCG (represented by the "Diff (T2-Cx)" column), none of the results was statistically significant at the 0.05 level, with the effect size ranging from 0.03 (Activity 3) to 0.07 (Activity 2). On the other hand, the difference between the not meeting adequate implementation group (T1) and the VCG, as expected, was small and not statistically significant, with the magnitude of the effect size not exceeding 0.05.

Table 7. Impact of ASSISTments With vPLC by the Level of Implementation in Key Component 1

	Adjusted mean	*n*	SD	Diff (T2-Cx)	SE	P	Hedges' *g*	Diff (T1-Cx)	SE	P	Hedges' *g*
T2	224.19	2,470	16.711	0.91	0.608	0.138	0.06				
T1	222.75	385	20.555					-0.529	0.887	0.552	-0.03

	Adjusted mean	*n*	SD	Diff (T2-Cx)	SE	P	Hedges' *g*	Diff (T1-Cx)	SE	P	Hedges' *g*
Cx	223.28	2,855	15.048								

***Note*. T2 refers to those treatment students who were taught by the teachers who met adequate implementation (Key Component 1) or were in the classes that met adequate implementation (Key Component 2–4); T1 refers to other treatment students who were taught by the teachers who did not meet adequate implementation or were in the classes that did not meet adequate implementation; Cx is the VCG.**

Table 8. Impact of ASSISTments With vPLC by the Level of Implementation in Key Component 2

	Adjusted mean	*n*	SD	Diff (T2-Cx)	SE	P	Hedges' *g*	Diff (T1-Cx)	SE	P	Hedges' *g*
T2	224.29	565	18.378	1.05	1.147	0.36	0.07				
T1	223.34	2181	16.995					0.105	0.341	0.758	0.01
Cx	223.23	2,855	15.048								

Table 9. Impact of ASSISTments With vPLC by the Level of Implementation in Key Component 3

	Adjusted mean	*n*	SD	Diff (T2-Cx)	SE	P	Hedges' *g*	Diff (T1-Cx)	SE	P	Hedges' *g*
T2	223.78	2,339	17.285	0.55	0.394	0.164	0.03				
T1	222.43	407	17.078					-0.800	0.581	0.169	-0.05
Cx	223.23	2,855	15.048								

Table 10. Impact of ASSISTments With vPLC by the Level of Implementation in Key Component 4

	Adjusted mean	*n*	SD	Diff (T2-Cx)	SE	P	Hedges' *g*	Diff (T1-Cx)	SE	P	Hedges' *g*
T2	224.16	586	17.228	0.93	1.068	0.385	0.06				
T1	223.35	2160	16.910					0.114	0.335	0.734	0.01
Cx	223.23	2,855	15.048								

Teachers' Use of Data to Inform and Adjust Instructional Practices, and Their Associations With Student Learning Outcome (Research Question 5)

Table 11 presents the descriptive statistics for the variables being studied, and Table 12 provides the corresponding correlation matrix among those variables. Overall, the correlations between teachers' self-reported use of data, based on their responses to the post-intervention survey and instructional log, and their participation in the vPLC or the use of ASSISTments (those values in bold) were small (all < 0.1) and not significant at the 0.05 level.

Table 11. Summary of Descriptive Analysis on the Implementation Variables and Teacher Use of Data

Variable	*n*	Mean	SD	Min	Max
Participation in the vPLC	59	3.46	0.934	1	4
Use of ASSISTments	56	4.02	1.083	1	6
Use of data to inform adjustment in classroom instruction	59	2.00	1.130	0	4
Use of data to inform in-class review	59	1.10	0.736	0	2

***Note*. Implementation variables are participation in the vPLC and use of ASSISTments; the last two variables represent teachers' use of data to inform and adjust instructional practices.**

Table 12. Correlation Matrix for Implementation Variables and Teacher Use of Data

	1	2	3	4
1. Participation in the vPLC	-			
2. Use of ASSISTments	0.36*	-		
3. Use of data to inform adjustment in classroom instruction	**-0.02**	**-0.04**	-	
4. Use of data to inform in-class review	**0.08**	**0.03**	0.19	-

***significant at the 0.05 level**

***Note*. Those values in bold are the correlation coefficients between the implementation variables (1 and 2) and teacher use of data (3 and 4).**

In contrast, teachers' use of data to inform in-class review was found to be positively and significantly correlated with the student learning outcome (coefficient = 1.59, *p* = 0.032). This suggests that greater use of data to guide review of student work was linked to improved student learning. On the other hand, teachers' use of data to inform adjustment of classroom instruction showed no significant association with the student learning outcome (coefficient = 0.05, *p* = 0.915) (Table 13).

Table 13. Summary of Regression Analysis on Student Learning Outcome by Teacher Use of Data

Predictor	Coefficient	Robust se	*p*	95% confidence interval
Use of data to inform classroom instruction	0.05	0.47	0.915	-0.87 – 0.97
Use of data to inform in-class review	1.59	0.74	0.032*	0.13 – 3.04

***significant at the 0.05 level**

Associations Between Student Learning Outcome and Student- and Class-Level Use of ASSISTments Platform (Research Question 6)

Descriptive statistics for the student- and class-level variables representing use of the ASSISTments platform in the analysis are reported in Tables 14 and 15.

Table 14. Summary of Descriptive Statistics for Student-Level Usage Variables

Usage variable	*n*	Mean	SD	Min	Max
Total number of minutes students worked in ASSISTments	2,657	350.75	344.781	0.92	3005.28
Total number of problems completed	2,657	342.43	355.048	2.00	2486.00
Total number of assignments completed	2,672	36.02	30.016	0	275.00
Average number of days per week a student worked in ASSISTments	2,657	1.86	0.494	1.00	4.09
Average number of minutes per week students worked on assignments	2,657	15.11	10.033	0.15	81.99

Table 15. Summary of Descriptive Statistics for Class-Level Usage Variables

Usage variable	*n*	Mean	SD	Min	Max
Total number of weeks with one or more assignments assigned	148	24.47	6.736	2	36
Total number of assignments assigned	148	69.52	43.103	3	310
Proportion of assignments that were non–Skill Builder assignments	149	0.70	0.240	0.09	1
Proportion of reports viewed	148	0.67	0.219	0	1

Tables 16 and 17 summarize the associations between the usage variables—one set at the student level and one at the class level—and student posttest scores. Given the large sample size at the student level, a significance threshold of $p = 0.01$ was used instead of 0.05 to determine whether the associations between student-level usage and math outcome were statistically significant. For student-level analyses (one-level models), partial eta squared was also calculated to estimate the effect size of the associations.

All student-level usage variables were positively and significantly associated with the student learning outcome at the 0.01 level (and even at the 0.001 level), suggesting that greater usage was related to higher performance. However, effect sizes as indicated by partial eta squared were small: None of the variables explained more than 3 percent of the variance in the outcome, most of which was accounted for by the pretest scores. The largest effect was observed for "total number of assignments completed" (partial eta squared = 0.034, or 3.4%). At the class level, only one variable—total number of assignments assigned—was positively associated with student math achievement ($p = 0.021$).

These analyses are exploratory and should not be interpreted as evidence of causal relationships between use of ASSISTments and student math achievement.

Table 16. The Association Between the Student-Level Usage Data and Student Posttest Scores

Usage variable	One-level model			Two-level model	
	Coefficient	*p*	Partial eta squared	Coefficient	*p*
Total number of minutes students worked in ASSISTments	0.003	<.001***	0.012	0.005	<.001***
Total number of problems completed	0.003	<.001***	0.011	0.005	<.001***
Total number of assignments completed	0.059	<.001***	0.034	0.097	<.001***
Average number of days per week a student worked in ASSISTments	1.407	<.001***	0.006	2.936	<.001***
Average number of minutes per week students worked on assignments	0.095	<.001***	0.011	0.130	<.001***

***significant at the 0.001 level

Table 17. The Association Between the Class-Level Usage Data and Student Posttest Scores

Usage variable	Three-level model	
	Coefficient	*p*
Total number of weeks with one or more assignments assigned	0.143	0.122
Total number of assignments assigned	0.023	0.021*
Proportion of assignments that were non–Skill Builder assignments	0.168	0.951
Proportion of reports viewed	0.210	0.948

*significant at the 0.05 level

Factors That Hinder or Facilitate Implementation: Insights From School Contexts and Teacher Experiences (Research Question 7)

To examine how vPLC-augmented ASSISTments was implemented across participating schools, the research team collected qualitative data through interviews with principals and teachers. These interviews provided insights into school contexts, educators' responses to the intervention, and the factors that facilitated or hindered its implementation. The following section summarizes the key themes that emerged from the analysis.

Understanding Implementation Context

Contextual data at the school, district, and community levels were gathered from principal interviews. Most principals emphasized the importance of data-informed decision-making (e.g., data meetings with teachers that included analyzing exit tickets). About half of schools granted teachers autonomy in selecting curricula or supplemental programs used in class. About half of the schools had relatively isolated teachers; teachers lacked support or community at small, rural schools. Most principals noted that their schools or communities were underresourced (e.g., many students lacked access to computers at home), and more than half expressed concern about their students' mathematics performance. Few schools demonstrated a strong focus on personalized learning. Overall, principals reported positive views toward implementing ASSISTments in their schools and were generally receptive to and supportive of the intervention.

Features That Improved Implementation

Teachers identified several features of the intervention that supported effective implementation. A commonly cited strength was the immediate feedback provided to students as they solved problems, which helped them recognize and correct mistakes in real time. Many teachers also highlighted the value of Skill Builders, which they frequently used to provide students with practice on individual, standards-aligned skills. About half of teachers appreciated the reports in ASSISTments, which were useful for identifying areas where their students struggled. Many teachers found the platform easy to use. Most teachers appreciated the vPLCs, noting that they fostered a sense of community among educators and provided valuable support for those who were less familiar with ASSISTments.

Implementation Challenges

Teachers also reported several challenges that made implementation more difficult. Some experienced usability issues with the platform, such as difficulty locating and assigning problems, a preference for editing problems rather than using only prebuilt problems, and challenges with integrating ASSISTments with their learning management systems. Students also encountered usability difficulties, including entering answers in the required formats and uploading pictures of their drawn work when prompted. Some teachers preferred that certain assignments—particularly those requiring drawings or showing detailed work—be completed on paper. Time constraints posed another barrier because some teachers struggled to find the time to fit ASSISTments into their schedules, and limited student access to devices at home made it difficult to assign the platform for homework.

Changes in Teachers' Formative Assessment Practices

Interviews indicated that the intervention led teachers to make changes in their formative assessment practices. About half of the teachers reported modifying the way they assigned independent practice (Step 1), often by assigning fewer problems or selecting more targeted problems for their students to solve. Most teachers shared that the way their students completed independent practice (Step 2) changed due to the intervention, emphasizing that the immediate feedback of ASSISTments improved students' independent practice work. They reported that students were motivated about and confident in their work, completed it at higher rates, and worked more independently and deliberately. Most teachers reported that they had changed the way they viewed and used data (Step 3). With ASSISTments, they were better able to use data to identify their students' challenges and misconceptions, and some used data to guide their instruction and select problems for whole-class review. Finally, more than half of teachers reported changing the way they reviewed problems with their students (Step 4), shifting problem review toward more targeted discussions that focus on common errors and misconceptions.

Effects on Student Self-Regulated Learning

Several themes emerged from teacher interviews regarding the effects of the intervention on students' SRL. Nearly all teachers reported observing at least one SRL-related outcome. More than half indicated that ASSISTments encouraged students to take greater responsibility for their own learning and become more self-directed in their math work. Some teachers also noted that the intervention promoted greater effort and diligence. In addition, some shared that the intervention improved students' attitudes and motivation toward math and increased their recognition that mistakes are an important part of the learning process.

Positive Experience With vPLCs

Teachers consistently described the vPLCs as a positive experience that fostered collaboration, strengthened their instructional practices, and reduced professional isolation. Many highlighted the sense of teamwork and shared learning experience it created, noting that it felt like "one big team working together" to figure out how to use ASSISTments more effectively. The vPLC also helped teachers more effectively engage in formative assessment practices, helping them learn to customize problem sets and use data to guide instruction, reteaching, and pacing decisions. For teachers working in smaller or rural schools and lacking support from other math teachers at the same grade levels, the vPLC provided an especially valuable source of professional connection, allowing them to hear from and engage with peer educators across the country. Finally, teachers emphasized that the vPLC not only enhanced their teaching but also saved their time, as it streamlined lesson planning and clarified instructional priorities in ways that benefited both teachers and students.

Cost-Effectiveness Analysis

A cost analysis was conducted to estimate the cost of the resources required to implement the intervention in classrooms. It was conducted using the ingredients method (Levin et al., 2018). Data were collected for two categories: (a) training and support and (b) program implementation costs. Under each category, there are several sub-ingredients that were necessary for implementing the ASSISTments program during the study period. Ingredients common to both treatment and comparison groups include school infrastructure costs (such as laptops, headphones, and facility space) and students' time on the use of the program platform. They are not included in the cost analysis.

Due to the cost savings from the program implementation side, the total cost, including the costs associated with training and support, is -$64,376.85. It indicates that the implementation of ASSISTments does not add additional costs to the participating schools and teachers. It actually saves money, particularly on the teacher's instructional time in assigning and reviewing homework and providing feedback to their students. Given that the analytic sample consists of 2,855 students from 59 teachers, the average savings per student is $22.55.

The cost-effectiveness ratio is -$563.72 based on dividing the average cost savings per student (-$22.55) by the program impact of .04 standard deviations. Since the program's impact is positive (though small and not statistically significant), it suggests that the use of ASSISTments could produce a positive impact on student math learning outcomes while reducing per-student costs.

The detailed list of ingredients and their estimated costs are summarized in Table D1 in Appendix D.

Conclusion and Discussion

The findings suggest that ASSISTments, when paired with a vPLC, provides a scalable, low-cost, effective model for strengthening math instruction across varied educational contexts. Its flexibility makes it particularly well-suited for rural schools where teachers often experience professional isolation and limited access to in-person professional learning and support. The vPLC not only facilitated professional development but also fostered a sense of community, enabling teachers to share strategies and address implementation collaboratively within their existing schedules.

Importantly, the intervention demonstrated promise in supporting the learning of *all* students, particularly those students with low prior performance. Students scoring below the 50th percentile on the pretest outperformed their peers in the VCG, suggesting the potential of ASSISTments to narrow achievement gaps and contribute to recovery from pandemic-related learning loss. Teachers expressed enthusiasm for the platform, and the study showed that the intervention can be implemented with adequate fidelity at scale, even in underresourced schools.

The study underscores several important considerations for scaling educational technology in diverse school settings, particularly in underresourced schools. First, the impact of ASSISTments was not attributable solely to the platform. The impact was also attributable to its integration with a thoughtfully designed vPLC. By creating a space for teachers to connect, share, and improve together, the vPLC helped overcome a critical barrier in rural and small schools: limited access to collaborative professional learning opportunities.

Second, the positive effects observed among lower performing students highlights the promise of technology-enhanced formative assessment tools, when implemented strategically and with fidelity, to improve math learning. Teachers consistently pointed to the value of immediate feedback, targeted practice, and real-time actionable data for enhancing student engagement, independence, and SRL and for strengthening their own formative assessment practices.

At the same time, the study identified challenges that need to be addressed to support broader adoption. Teachers reported difficulties with navigating the platform, editing questions, and integrating ASSISTments with learning management systems. These usability barriers can discourage uptake, especially among teachers who are less comfortable with technology. In addition, limited access to student devices at home hampered the platform's use as a homework or extended learning tool. Addressing these barriers through technical refinements and improvements in school- and district-level infrastructure will be essential for successful scaling.

Variation in teacher autonomy, collaboration, and support across schools also underscores the importance of local implementation conditions. Effective implementation of ASSISTments will require not only training and technical assistance but also school leadership that promotes a data-driven decision-making culture and ensures that teachers have the time and flexibility to integrate the platform into their daily instruction.

Taken together, these findings emphasize the value of pairing high-quality technology tools with scalable professional learning supports. As schools continue to navigate the challenges of postpandemic recovery and expand access to high-quality STEM instruction, solutions such as ASSISTments, particularly when grounded in supportive implementation structures, offer a promising path forward.

Looking ahead, future work will focus on examining the relationship between platform usage intensity and student learning outcomes and on exploring variation in implementation patterns between rural and nonrural schools. Additionally, ongoing refinement of platform usability and integration with existing school systems will be essential for maximizing impact. This report's findings offer actionable insights for teachers, administrators, and policymakers seeking to adopt evidence-based, technology-enhanced solutions to improve math outcomes nationwide.

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Appendix A: Content of the vPLCs

Table A1. Content of the vPLCs

vPLC topic	Learning content	Examples
Session 1: Establishing High Expectations for All Learners	• Routines and structures that create a supportive environment and help students foster a sense of belonging • National Council of Teachers of Mathematics (NCTM) guidelines for teaching mathematics with high expectations—breakout discussion • Upholding high expectations while assigning a problem set—practice within ASSISTments	• Recognize that each and every student, from pre-K through college, is able to solve challenging mathematical tasks successfully • Build in each student a positive mathematical identity and a sense of urgency • Design instruction that builds on students' prior knowledge and experiences • Monitor indicators of student performance: time spent on task, completion, timeliness, redos, mathematical reasoning/shown work, question asking, etc. • Emphasize practice and acknowledge that everyone learns at different speeds • Explain to students the value of their ASSISTments work in driving report data and shaping subsequent instruction • **Teachers' practice within ASSISTments:** Assign an upcoming problem set that upholds high expectations for all learners
Session 2: Assignment Report Overview	• Report uses and topics • Assignment report video tour • Your assignment report analysis • Actionable next steps for instruction—breakout discussion	• Consistent routines for how and when • Data are scores, not grades • Scores supports teaching and learning • Multiple attempts, hints, and redos engage students • Report overview: scores, symbols, common wrong answers, time, hints • Examples of actionable next steps: randomize Skill Builders, switch seats, create small groups for reteaching, inform upcoming instruction • Skill Builders check for mastery

vPLC topic	Learning content	Examples
Session 3: Common Wrong Answer and Student Details Report	• Overviewing assignment reports and watching highlight video • Analyzing common wrong answers • Selecting individual students or common problems for reteaching—breakout discussion	• Assignment Report Features: Common wrong answer, student-level details, performance summary, student progress cards, score symbols key • Common Wrong Answers report illuminates alternative student conceptions • Student performance indicators: time spent on a problem before asking for a hint, consistent yellow/red problems • Model the correct way to enter answers considering units, input format, and vocabulary • Identify patterns in common wrong answers
Session 4: Creating a Collaborative Learning Environment	• Assignment report highlights—Common Wrong Answer, Reviewing Reports With Students, Student Assignment Report (student view) • Routines and structures • Opening comments or questions that promote a collaborative learning culture—breakout discussion	• Identification of common misconceptions from percentage data • Projection of anonymized data • Student view of data: individual student score, class average on assignment, and viewing of teacher's open response feedback • Routines and structures: Modeling mistake-making and the learning process, outlining the daily agenda on the board, setting days and deadlines for ASSISTments assignments, celebrating mistakes as opportunities for learning, having students share common wrong answers • Analysis conducted with the class on how students arrived at a common wrong answer

vPLC topic	Learning content	Examples
Session 5: ASSISTments Data to Inform and Differentiate Instruction	• Skill Builders and instructional recommendations • Rationale for using Skill Builders • Interpretation of the Skill Builders Report • Score Chips • 7th grade instructional recommendations and lesson plans • Data that indicate a need for differentiation—breakout discussion	• Skill Builders: cover one specific skill, are similar in style, offer built-in student tutor, provide clickable progress cards for each student; students answer 3 in a row correctly to complete; students answer 10 wrong in a row and the problem set will end until next day • Differentiation of students by small, flexible groups • Selection of small skills within the larger lesson for extra practice and individualized instruction • Use of data to adapt the next day's lesson plan • The finding and assigning of advanced skills from the next grade level content
Session 6: Constructing Effective Individual Feedback	• Report highlight: Student Details Report (teacher view) • Use of data reports to make the most of one-on-one student conversation or whole-class discussion • Information on instruction and assignment differentiation • Data that indicate a need for individualized feedback and feedback examples—breakout discussion	• Check in with students on mistakes, hints usage, understanding of the question, time spent on problems, effort • Review Student Reflection Forms: reason answer was incorrect and space for reattempting the problem • Offer opportunities to excel for enrichment instead of more practice • Review data: time and date the student began the problem, amount of time since the last action • Score and provide feedback on the student's open response

vPLC topic	Learning content	Examples
Session 7: Orchestrating Class Discussions Around Open Response Questions	• Report highlight: Scoring open response questions • Quick comments • 5 process standards for mathematics defined by NCTM • 5 practices for orchestrating productive mathematical discussions • Example problem: How would you strategically sequence and share student work leveraging ASSISTments open responses?—breakout discussion • Cost–benefit analysis: Reviewing student-generated solutions versus teacher-constructed explanations	• Quick Comments: library of comments, customization, adaptive system (AI continuously learns) • Student averages are only impacted if instructor decides to enter an open response score • Routine in place to prompt students to check scores/feedback • 5 Process Standards: problem-solving, reasoning and proof, communication, connections, representation • 5 Practices: anticipate likely student responses to challenging problems, monitor students' responses (while in groups), select students to present their answers, sequence student responses to display in order, connect student responses and key math ideas • Problem review: teachers plan math connections that they want students to make between displayed student work samples

vPLC topic	Learning content	Examples
Session 8: Student Engagement and Motivation	• Three components of motivation—autonomy, competence, and relatedness—and support of ASSISTments • Ways ASSISTments may support the three components of motivation • Strategies to help students avoid spring burnout; ASSISTments routines • 5 ways to motivate students to learn math; ASSISTments routines • Selection of strategies from the three articles that you plan to use to engage and motivate your students while leveraging ASSISTments • The specific way you will use this strategy and the way it supports student engagement and motivation	• Autonomy is a "sense of initiative and ownership in one's actions" • Competence is a "feeling of mastery" and a sense that with effort a student can "succeed and grow" • Relatedness is when the school setting "conveys respect and caring," resulting in students feeling "a sense of belonging and connection" • Maintenance of learning momentum: prioritize movement, break down large goals into small and manageable daily objectives, avoid mental inertia by adjusting pacing to match students' learning speed, celebrate success by providing targeted feedback about the positive aspects of student work • Transformational Teaching: happens when students feel less anxious about math • Engagement and Encouragement: students seek ways to be inspired to reach their fullest potential and achieve learning goals • Acknowledgement and Awareness: rely on learning from making mistakes and falling forward • Consistency in Holding Students Accountable for Their Success: provide students with a weekly checklist detailing clear expectations and learning goals

vPLC topic	Learning content	Examples

Session 9: (Optional) Celebrating Our ASSISTments Journey	• Share and celebrate: Most significant takeaways from vPLC learning and ASSISTments implementation	• Quotes from teachers:
		  ◦ "[The vPLC has helped me through] feedback and discussion with other teachers that enabled course corrections, improvements, and fresh perspectives. [It also provided] the ability to use a new program, with fidelity, to track student progress, provide consistent feedback, and use data to drive instruction."
		  ◦ "The best part of Assistments is the way it is easily connectable to my daily routine. I used to think that Assistments would be hard to get students into a routine, but now I know that it is a seamless process."
		  ◦ "After a little experience, I learned how to offer redo problems and incorporate skill builders for the students to practice necessary skills."
		  ◦ "The culture of the classroom has changed where students are taking their learning and strengthening it on their own/requesting different practice problems."
		  ◦ "I used to think ASSISTments was too challenging to keep up with grading all the extended responses, but now I know that going over those questions as a class to give feedback and talk things out is more beneficial to the whole class!"
		  ◦ "The best part of ASSISTments is the detailed reports. I like seeing the common mistakes, how long it took students to complete each question and what they put in each time they answered the question incorrectly."
		• Feedback:
		  ◦ "I would love to be able to extend [Skill Builders] to 5 in a row for my classes that need a little more challenge. I really like the problems they have and find myself using Skillbuilders more than assignments."

vPLC topic	Learning content	Examples
Session 10: (Optional) Teacher Discussions	• Review of instructional recommendations • Successful formative assessment routines • Differentiation while leveraging ASSISTments; resources	• The way to build a successful routine that students are invested in requires access to quick data that can be shared with students and used to drive subsequent instruction • Additional resources: Skill Builder strategies; how to create a custom problem set

Appendix B: Implementation Fidelity

Table B1. Implementation Fidelity Key Component 1: Teacher Virtual Professional Learning Community (vPLC)

	New-User Training	Ongoing virtual meetings	Asynchronous participation in online community activities via Slack	All indicators
Definition	2 hours of virtual training to learn how to use the platform	Synchronous online bimonthly meetings during school year (*n* = 8, 75-minute sessions) to share what is being learned and challenges and to dive into topics related to the effective use of ASSISTments	30 minutes a week to complete online assignments that enhance the synchronous sessions	NA
Unit of Implementation	Teacher	Teacher	Teacher	NA
Data source(s)	Attendance records and exit tickets collected by Lesley University and The ASSISTments Foundation	Attendance records collected at the meetings by LU facilitator	Completion of assignments in Slack	NA

	New-User Training	Ongoing virtual meetings	Asynchronous participation in online community activities via Slack	All indicators
Data collection (who, when)	By 09/15 attendance list shared with evaluator via Google Drive	Summaries of attendance records will be submitted to evaluator 12/15 & 6/15	LU monitors teachers' participation in online community activities and access to resources and shares record with WestEd by 6/15	NA
Scores for levels of implementation at unit level	0 (low) = did not attend 1 (moderate) = attended or did not need to attend (not a new user)	0 (low) = 4 or fewer sessions 1 (moderate) = 5–6 sessions 2 (high) = 7–8 sessions	0 (low) = 24% of total assignments complete 1 (moderate) = 25–49% of assignments complete 2 (high) = 50% or more of assignments complete	0–6
Threshold for adequate implementation at unit level	Adequate implementation at teacher level = score of "1"	Adequate implementation at teacher level = score of "1"	Adequate implementation at teacher level = score of "2"	Teacher level: Adequate implementation score = 4
Roll-up to sample level (score and threshold for adequate implementation at sample level)				Sample level 0 = < 25% teachers with score = 4 1 = 26–50% teachers with score = 4 2 = 51–75% teachers with score = 4 3 = > 75% teachers with score = 4 Threshold for fidelity = score of "3"

Table B2. Implementation Fidelity Key Component 2: Prebuilt Content for Math Work Assignment

	Teachers assigning math work via ASSISTments regularly over the school year	Teachers assigning math work via ASSISTments regularly over the school year	All indicators
Definition	Teachers assign independent practices regularly over the school year via ASSISTments by choosing regular assignments	Teachers assign independent practices via ASSISTments regularly by choosing regular assignments, or, if desired, Skill Builder	NA
Unit of Implementation	Class	Class	NA
Data source(s)	Computer system records	Computer system records	NA
Data collection (who, when)	Worcester Polytechnical Institute (WPI) will share the fall and spring assignment records with evaluator by 1/15 and 7/15	WPI will share the fall and spring assignment records with evaluator by 1/15 and 7/15 Note: the denominator will be total number of weeks teacher was active that school year (i.e., created at least 1 assignment)	NA
Scores for levels of implementation at unit level	0 (low) = at least 1 regular assignment a week per class for 8 weeks or fewer 1 (moderate) = at least 1 regular assignment a week per class for 9–16 weeks 2 (high) = at least 1 regular assignment a week per class for 17 or more weeks	0 (low) = no assignment 1 (moderate) = 1–2 assignments per week per class on average during the weeks when they used ASSISTments 2 (high) = 3 or more assignments per week per class average during the weeks when they used ASSISTments	0–4

	Teachers assigning math work via ASSISTments regularly over the school year	Teachers assigning math work via ASSISTments regularly over the school year	All indicators
Threshold for adequate implementation at unit level	Adequate implementation at class level = score of "2"	Adequate implementation at class level = score of "1"	Class level: Adequate implementation score = 3
Roll-up to sample level (score and threshold for adequate implementation at sample level)			Sample level 0 = < 25% classes with score > = 3 1 = 26–50% classes with score > = 3 2 = 51–75% classes with score >=3 3 = > 75% classes with score > = 3 Threshold for fidelity = score of "3"

Table B3. Implementation Fidelity Key Component 3: Support of Data-Driven Adaptation in Instruction

	Teachers review reports	All indicators
Definition	Teachers log in and open reports for regular assignments for their classes produced by the system	NA
Unit of implementation	Class	NA
Data source(s)	Computer system records	NA
Data collection (who, when)	WPI will share the fall and spring assignment records with evaluator by 1/15 and 7/15	NA
Scores for levels of implementation at unit level	0 (low) = open reports for less than 50% of assignments 1 (moderate) = open reports for 50–85% of assignments 2 (high) = open reports for more than 85% of assignments	0–2
Threshold for adequate implementation at unit level	Adequate implementation at class level = score of "1"	Class level: Adequate implementation score = 1
Roll-up to sample level (score and threshold for adequate implementation at sample level)		Sample-level 0 = < 25% classes with score > =1 1 = 26–50% classes with score > =1 2 = 51–75% classes with score > =1 3 = > 75% classes with score > =1 Threshold for fidelity = score of "3"

Table B4. Implementation Fidelity Component 4: Immediate Support for Students

	Students solve problems in ASSISTments	All indicators
Definition	Students solve enough number of problems in ASSISTments and receive immediate feedback on correctness of their answer and hints on Skill Builder problems	NA
Unit of implementation	Student	NA
Data source(s)	Computer system records	NA
Data collection (who, when)	WPI will share the fall and spring assignment records with evaluator by 1/15 and 7/15	NA
Scores for levels of implementation at unit level	0 (low) = A student solves 33% or fewer of problems assigned to them from regular assignments 1 (moderate) = A student solves 33–67% of problems assigned to them from regular assignments 2 (high) = A student solves 68% or more of problems assigned to them from regular assignments	0–2
Threshold for adequate implementation at unit level	Adequate implementation at student level = score of "2"	Student level = score of "2"

	Students solve problems in ASSISTments	All indicators
Roll-up to next higher level if needed (score and threshold): Indicate level	Class level 0 = < 25% students with score of "2" 1 = 26–50% students with score of "2" 2 = 51–75% of students with score of "2" 3 = > 75% students with score of "2" Threshold for fidelity = score > "2" (adequate implementation)	
Roll-up to sample level (score and threshold for adequate implementation at sample level)		Sample level 0 = < 25% classes with score > = 2 1 = 26–50% classes with score > = 2 2 = 51–75% classes with score > = 2 3 = > 75% classes with score > = 2 Threshold for fidelity = score of "3"

Appendix C: Implementation Fidelity Results by Cohort

Table C1. Fidelity of Implementation Results for Implementation Cohort 1 (2022–23)

Intervention component	Implementation measure (total number of measurable indicators representing each component)	Sample size at the sample level (# of schools, districts, etc.)	Component-level threshold for fidelity of implementation for the unit that is the basis for the sample level	Evaluator's criteria for "implemented with fidelity" at sample level	Component-level fidelity score for the entire sample	Implemented with fidelity? (Yes, No, N/A)
Teacher vPLC	3 measures	16 teachers	Sum all indicators **Adequate implementation = 4**	75% of teachers with score of 4 or above	87.5% (14/16) met threshold	Yes
Prebuilt Content for Math Work Assignment	2 measures	39 classes	Sum both indicators **Adequate implementation = 3** Teachers assigned at least one regular problem set for at least 17 weeks	75% classes with score > = 3	92% (36/39) met threshold	Yes
Support of Data-Driven Adaptation in Instruction	1 measure	39 classes	**Adequate implementation = 1** Teachers open reports for at least half of the regular assignments for the class	75% classes with score > = 1	90% (35/39) met threshold	Yes

Intervention component	Implementation measure (total number of measurable indicators representing each component)	Sample size at the sample level (# of schools, districts, etc.)	Component-level threshold for fidelity of implementation for the unit that is the basis for the sample level	Evaluator's criteria for "implemented with fidelity" at sample level	Component-level fidelity score for the entire sample	Implemented with fidelity? (Yes, No, N/A)
Immediate Support for Students	1 measure	39 classes	**Adequate implementation = 2** 75% of students complete at least 68% of problems assigned to them from regular assignments	75% classes with score > = 2	72% (28/39) met threshold	No

Table C2. Fidelity of Implementation Results for Implementation Cohort 2 (2023–24)

Intervention component	Implementation measure (total number of measurable indicators representing each component)	Sample size at the Sample Level (# of schools, districts, etc.)	Component-level threshold for fidelity of implementation for the unit that is the basis for the sample level	Evaluator's criteria for "implemented with fidelity" at sample level	Component-level fidelity score for the entire sample	Implemented with fidelity? (Yes, No, N/A)
Teacher vPLC	3 measures	46 teachers	Sum all indicators **Adequate implementation = 4**	75% of teachers with score of 4 or above	87% (40/46) met threshold	Yes
Prebuilt Content for Math Work Assignment	2 measures	129 classes	Sum both indicators **Adequate implementation = 3** Teachers assigned at least one regular problem set for at least 17 weeks	75% classes with score > = 3	71% (92/129) met threshold	No

Intervention component	Implementation measure (total number of measurable indicators representing each component)	Sample size at the Sample Level (# of schools, districts, etc.)	Component-level threshold for fidelity of implementation for the unit that is the basis for the sample level	Evaluator's criteria for "implemented with fidelity" at sample level	Component-level fidelity score for the entire sample	Implemented with fidelity? (Yes, No, N/A)
Support of Data-Driven Adaptation in Instruction	1 measure	129 classes	**Adequate implementation = 1** Teachers open reports for at least half of the regular assignments for the class	75% classes with score > =1	92% (119/129) met threshold	Yes
Immediate Support for Students	1 measure	129 classes	**Adequate implementation = 2** 75% of students complete at least 68% of problems assigned to them from regular assignments	75% classes with score > = 2	62% (80/129) met threshold	No

Appendix D: Cost-Effectiveness Analysis

WestEd conducted a cost analysis to estimate the cost of the resources required to implement the virtual professional learning community (vPLC)–augmented ASSISTments in the middle school classrooms. The cost analysis was conducted using the ingredients method (Levin et al. , 2018). Data were collected for two major categories: (a) training and support and (b) program implementation. Under training and support, there are two cost areas: ASSISTments program ingredients and teacher/participant ingredients. Each of these two areas has several sub-ingredients (see Tables D1-D4). Under program implementation, there is one major cost area: the teachers' instructional time associated with ASSISTments, which has several sub-ingredients.

The ASSISTments is a web-based platform. In this study, teachers and students leveraged existing devices and networks available in school or at home to implement ASSISTments. No specialized hardware or software was provided to use the platform beyond the computers already provided to students. For this reason, school infrastructure-related costs (such as laptops, headphones, and facility space) are not included in the cost to implement ASSISTments. Similarly, students' time on the use of the ASSISTments platform is not included as part of the cost because the students in the comparison group would have done so on other platforms. The ingredients identified and summarized in Tables D1-D4 are necessary for implementing the ASSISTments program during the study period.

The hourly rate for the trainers was provided by the developers of ASSISTments. They also provided information related to the number of hours and the number of groups for the ingredients associated with the trainers. The number of groups refers to the frequency of an event that took place. For example, to accommodate teachers' schedules, the orientation (75 minutes each item, led by two trainers or facilitators) was held five times, and each time consisted of 8–12 teachers. For the technical support (such as how to upload the assignments to the ASSISTments platform), the research team estimated that each teacher received an average of 45 minutes throughout the study from any trainer. That is why 59 (teachers) is the number of groups for that ingredient.

The hourly rate for teachers was estimated based on the data from the U.S. Bureau of Labor Statistics,[1] where it reported that in 2024 the median salary for middle school teachers across the United States. was $62,970 per year. With that information, researchers estimated the average hourly rate for teachers is $30.27.

The teachers' time in participating in the professional learning sessions and receiving additional technical support follows the time spent by the trainers on those ingredients. For program implementation, the change in teacher instructional time due to the implementation of ASSISTments was estimated. It includes "assigning assignments" to "providing individual student feedback" (those ingredients under the program implementation cost area). To do this, researchers compared the teacher's reported weekly time spent on each of these ingredients between the pre- and post-intervention surveys. The calculation used 29 weeks, assuming that, on average, the teachers assign homework to their students 80 percent of the time in a school year with a total of 36 weeks (36 * 0.8 = 28.8). Teachers would not assign homework for those weeks when the statewide testing takes place, there are local events (e.g., harvest times in rural communities, sports events or tournaments, long weekends or shorter weeks), and unplanned circumstances (e.g., teacher is out sick).

As it turns out, the use of the ASSISTments platform saved teachers' time on these activities because the number of hours decreased before and after the program implementation (Table D5). In other words, instead of adding costs to the teachers, the program actually saved teachers' instructional time in doing those activities as compared to the time spent before they started to use the ASSISTments platform. This is evidenced by the following quotes (as examples) from teachers:

> "[ASSISTments] allows me not to stress too much on looking [up] things. Especially with the short time … it was very easily for me to go because it's already separated by units. … It never takes me more than, I'm gonna exaggerate, 15 minutes. It is usually less, way less. But it's super easy. … If I wanna work with a set of problems or with Illustrative Math, specific topics or lessons, I can just sometimes just type it in the search bar. And it gives me everything, whatever I need. Or, or I'll go specifically to each of the topics and then check what do I wanna input in. … It doesn't take me time even to set up the assignment in Canvas is already like correlated. It makes it automatically. ... I don't have to take like that much time into it."

> "[Before ASSISTments] I was losing so much time grading … I couldn't grade everybody's homework every day."

> "So I mean, the fact that they're able to get that quicker response from those Cool Downs is a lot more efficient [compared with] pen paper or pencil paper homework

1 https://www.bls.gov/ooh/education-training-and-library/middle-school-teachers.htm

is in a way it changed a bit, but it's more for the efficiency part of it. 'Cause I can't be everywhere at once."

Due to the cost savings from program implementation, the total cost, including the costs associated with training and support, becomes -$64,376.85. It indicates that the implementation of ASSISTments does not add additional costs to the participating schools and teachers. It actually saves money, particularly on the teachers' instructional time in assigning and reviewing homework and providing feedback to their students. Given that the analytic sample consists of 2,855 students from 59 teachers, the average savings per student is $22.55.

Table D1. Cost by Ingredient: Training and Support (ASSISTments Program Ingredients)

Cost areas	Sub-ingredients	Unit	Cost per unit	Number of hours	Number of units	Number of groups	Total cost
ASSISTments trainer time	1 Orientation session (75 minutes) x 2 facilitators	Trainer	$65/hr	1.25	2	5	$812.50
ASSISTments trainer time	8 vPLC sessions (75 minutes per session) x 2 facilitators	Trainer	$65/hr	10.00	2	6	$7,800.00
ASSISTments trainer time	8 Slack activities (1 hour per activity)	Trainer	$65/hr	8.00	1	6	$3,120.00
ASSISTments trainer time	9 session preparations (2.5 hours per session) x 1 facilitator	Trainer	$65/hr	22.50	1	6	$8,775.00
Trainer or other support staff time	Technical support (45 minutes per teacher)	Trainer	$65/hr	0.75	1	59	$2,876.25
Subtotal	-	-	-	-	-	-	**$23,383.75**

Table D2. Cost by Ingredient: Training and Support (Teacher/Participant Ingredients)

Cost areas	Sub-ingredients	Unit	Cost per unit	Number of hours	Number of units	Total cost
Teacher time in professional learning	1 orientation session (75 minutes)	Teacher	$30.27/hr	1.25	59	$2,232.41
Teacher time in professional learning	8 vPLC sessions (75 minutes per session)	Teacher	$30.27/hr	10.00	59	$17,859.30
Teacher time in professional learning	8 Slack activities (30 minutes per activity)	Teacher	$30.27/hr	4.00	59	$7,143.72
Teacher time getting support	Technical support (45 minutes)	Teacher	$30.27/hr	0.75	59	$1,339.45
Subtotal	-	-	-	-	-	**$28,574.88**

Table D3. Cost by Ingredient: Program Implementation

Cost areas	Sub-ingredients	Unit	Cost per unit	Number of hours	Number of units	Total cost
Teacher instructional time associated with ASSISTments	Assigning assignments	Teacher	$30.27/hr	-14.64	59	-$26,146.02
Teacher instructional time associated with ASSISTments	Reviewing and/or grading student work	Teacher	$30.27/hr	-17.57	59	-$31,378.79
Teacher instructional time associated with ASSISTments	Planning class instruction	Teacher	$30.27/hr	-9.27	59	-$16,555.57

Cost areas	Sub-ingredients	Unit	Cost per unit	Number of hours	Number of units	Total cost
Teacher instructional time associated with ASSISTments	Revising class instructional plan based on student work	Teacher	$30.27/hr	-9.56	59	-$17,073.49
Teacher instructional time associated with ASSISTments	Providing individual student feedback	Teacher	$30.27/hr	-14.10	59	-$25,181.61
Subtotal	-	-	-	-	-	**-$116,335.48**

Table D4. Cost by Ingredient: Total Costs

Cost areas	Costs
Training and Support: ASSISTments program ingredients	$23,383.75
Training and Support: Teacher/participant ingredients	$28,574.88
Program Implementation	-$116,335.48
Total (savings) **(Sum of all cost areas)**	**-$64,376.85**
Average saving per student **(Total divided by number of students)**	**-$22.55**

Table D5. Instructional Time Spent by Teachers, Before and After the Implementation of ASSISTments

Tasks	Before ASSISTments (in minutes)	After ASSISTments (in minutes)	Diff (weekly, in minutes)	Diff (over the study period, in hours)
Assigning assignments	69.78	39.48	-30.29	-14.64
Reviewing and/or grading student work	109.19	72.84	-36.34	-17.57
Planning class instruction	100.21	81.03	-19.18	-9.27
Revising class instructional plan based on student work	57.61	37.81	-19.78	-9.56
Providing individual student feedback	68.27	39.91	-29.18	-14.10

The cost-effectiveness ratio is -$563.72 by dividing the average cost saving per student (-$22.55) by the program impact of .04 standard deviations. Since the program's impact is positive (though small and not statistically significant), it suggests that the use of ASSISTments could produce a positive impact on student math learning outcomes while reducing per-student costs.