Promising Long Term Effects of ASSISTments Online Math Homework Support

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Abstract. Math performance continues to be an important focus for improvement. Many districts adopted educational technology programs to support student learning and teacher instruction. The ASSISTments program provides feedback to students as they solve homework problems and automatically prepares reports for teachers about student performance on daily assignments. During the 2018-19 and 2019-20 school years, we conducted a large-scale randomized controlled trial to replicate the effects of ASSISTments in 63 schools in North Carolina in the US. 32 treatment schools implemented ASSISTments in 7th-grade math classrooms. Recently, we conducted a follow-up analysis to measure the long-term effects of ASSISTments on student performance one year after the intervention, when the students were in 8th grade. The initial results suggested that implementing ASSISTments in 7th grade improved students' performance in 8th grade and minority students benefited more from the intervention.

Keywords: ASSISTments, math learning, long-term effects, effective teaching, AI-based program

1 Introduction

Mathematics education continues to be an important focus for national improvement. Achievement gaps between demographic groups continue to be an important national and state-based concern. Due to the promise of technology as a tool for improving mathematics education and closing the achievement gap, the use of educational technology in K-12 education has expanded dramatically in recent years, accelerated by the COVID-19 pandemic. The AIED and intelligent tutoring systems researchers and developers have built numerous technology-based learning platforms and programs, but few of these products have been implemented at a large scale in authentic school classroom settings. ASSISTments [1] is one of the few digital platforms that have been used widely in the U.S. Over the past two years, ASSISTments use in schools increased significantly, going from supporting 800 teachers to supporting 20,000 teachers and their 500,000 students. At the beginning of the COVID pandemic, the US Department funded a rapid review to synthesize existing evidence in online programs that promoted learning, and ASSISTments was one of the few digital learning programs recommended for use in response to the COVID pandemic [2].

The ASSISTments platform is a technology-based, formative assessment platform for improving teacher practices and student math learning outcomes. As students work through problems and enter their answers into ASSISTments, the system provides immediate feedback on the correctness of answers and offers additional assistance in the form of hints or scaffolds. ASSISTments provides teachers with real-time, easily accessible reports that summarize student work for a particular assignment, which teachers can use to target their homework review in class and tailor instruction to their students' needs. ASSISTments was identified as effective at improving 7th grade student's learning and changing teacher's homework review practices during an efficacy study in Maine ([3,4], meeting What Works Clearinghouse standards without reservation, $g=.22$, $p<.01$). Escueta et al. [5] indicated that out of 29 studies they reviewed that met rigorous standards of randomization, ASSISTments was one of only "Two interventions in the United States [that] stand out as being particularly promising" (page 88).

Supported by the U.S. Department of Education, we conducted a large scale randomized controlled trial[1] to replicate the Maine study and see whether the found effects replicate in a heterogeneous population that more closely matches national demographics. In addition, we designed a follow-up study to measure the long-term effects of ASSISTments on student performance one year after the intervention was over. This late-breaking results paper reports on the findings from the recently completed preliminary analysis of the follow-up study. The follow-up study addresses two research questions: 1) *What is the impact of ASSISTments on student math outcomes at the end of Grade 8?* 2) *Do the effects of ASSISTments vary for students of different demographic characteristics?*

2 Background on ASSISTments

ASSISTments uses technology to give teachers new capabilities for assigning and reviewing homework and to give students additional support for learning as they do homework. Content in ASSISTments consists of mathematics problems with answers and hint messages. These mathematics problems are bundled into problem sets which teachers can use ASSISTments to assign to students in class or as homework. Students first do their assigned problems on paper and then enter their answers into ASSISTments to receive immediate feedback about the correctness of their answers, and/or hints on how to improve their answers or help separate multi-step problems into parts. One type of problem set is mastery-oriented "Skill Builders". Each skill builder provides opportunities for students to practice solving problems that focus on a targeted skill, until they reach a teacher-defined "mastery" threshold of proficiency (e.g., a streak of three correct answers on similar math problems). ASSISTments also automatically re-assessing students on skills and concepts that were "mastered" earlier at regular intervals and providing further opportunities for students to hone those skills.

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[1] The study has been pre-registered on Registry of Efficacy and Effectiveness Studies (REES) https://sreereg.icpsr.umich.edu/framework/pdf/index.php?id=2064
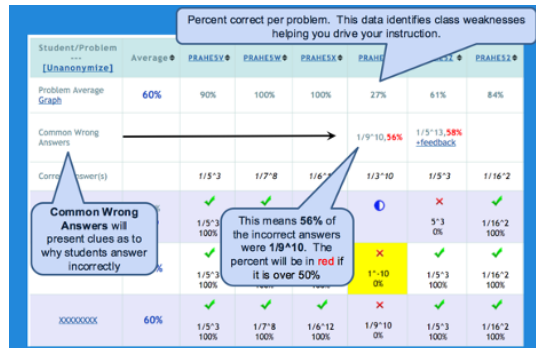
Fig. 1. An item report for teachers showing the results of 6 items.

ASSISTments provides teachers with real-time, easily accessible reports that summarize student work for a particular assignment in a grid format (e.g. Fig 1). These reports inform teachers about the average percent correct on each question, skills covered in the assignment, common wrong answers, and each student's answer to every question. Teachers use information about individual students to form instructional groups and address common difficulties.

The design and development of ASSISTments is built upon the theoretical foundations and empirical research. *Feedback* has been identified as a powerful way to increase student learning [6]. An extensive set of studies (e.g., [7,8,9]) has found significant learning gains in response to feedback within computer-based instruction. *Formative assessment* [10, 11] informs teachers of student learning and progress and students of their own performance in relation to learning goals. Several decades of research have shown formative assessment to be an effective way of improving both teaching and student learning [12, 13]. *Mastery learning* programs have been shown to lead to higher student achievement than more traditional forms of teaching [14, 15]. An IES Practice Guide [16] recommends *spacing practice* over time. Research has demonstrated that retention increases when learners are repeatedly exposed to content (see [17]).

3 Research Design

The replication study used a school-level, clustered randomized experimental design. Schools within each district were paired based on their demographic characteristics and student prior performance on state math and English language arts (ELA) tests and then randomly assigned to a treatment or business-as-usual control condition. All 7th math teachers in a school had the same assignment of condition. Teachers in the treatment schools used ASSISTments to support math homework. In the control condition, teachers continued their existing homework practices, including any use of online tools, but not had access to ASSISTments. The intervention was implemented by all Grade 7 teachers in treatment schools over two consecutive years—teachers learned how to use ASSISTments for a year (2018-19) and then we measured the immediate impact for students in teachers' second year of experience with the system (2019-20). Students who were in Grade 7 during the 2019-20 school year comprised the analytic sample for the research questions. The students maintained their conditions and were followed longitudinally for another year to Grade 8 when their Grade 8 performance (long-term impact) was measured at the end of Grade 8 (see Fig.2 for an overview). During the follow-up year in Grade 8, no interventions were be provided by the team

to 8th grade teachers or students, although the teachers may spontaneously choose to use ASSISTments on their own since ASSISTments is an open, free-access platform.

	Study Teachers	Study Students	Measures of Student Learning
2018-19: Warm-up	Learn to use ASSISTments with a different cohort of students	In 6th grade, no intervention	6th Grade State End of Grade Test (EoG) (Baseline)
2019-20: Measurement year	Use ASSISTments with 7th grade classrooms	In 7th grade, Use ASSISTments to complete homework assignments	7th Grade EoG (Immediate Outcome, missing due to COVID)
2020-21: Follow-up	No intervention	In 8th grade, no intervention	8th Grade EoG (Long Term Outcome)

Fig. 2. Study Overview

Sixty-three schools from 41 different districts were originally recruited into the sample and randomly assigned to condition (32 treatment schools and 31 control schools). The schools served several different grade levels (6-8, 8-12, K-8) and were distributed across rural, town, suburban, and city communities (33 rural, 11 town, 8 suburban, and 11 city). Of the 63 schools, 18 were charter schools, 45 were public schools, and 48 of the schools received Title 1 funding. 102 7th grade math teachers and their classrooms enrolled in the study. One hundred and two 7th grade math teachers and their classrooms enrolled in the study. Teachers in the 32 treatment schools implemented ASSISTments in their classrooms for homework support for two years. They received two days of training during each summer in 2018 and 2019, and additional coaching and technical assistance were distributed across the school years of 2018-19 and 2019-20 via webinars, video conferencing, and 2-3 times in-person visits each year.

The onset of COVID-19 forced the closure of study schools by the middle of March 2020 and the move to remote instruction. The state End-of-Grade test (EOG), which was to be the immediate student learning outcome, was canceled for spring 2020. Majority of schools in North Carolina remained in remote instruction during the 2020-21 school year and the EoG test resumed in spring 2021, when participating students of the study were in 8th grade.

4   Data, Analysis, and Findings

Student's long-term learning outcome was measured by state standardized Grade 8 End of Grade (EoG) math assessment. Student's 6th grade EoG scale scores served as the baseline measure, administered in 2018-19. Student demographic data accessed included gender, race/ethnicity, and economically disadvantaged status (eds). School-level covariates included average 6th grade EoG scale score, 7th grade enrollment size, school Title 1 eligibility, percentage of students with eds, and percentage of ethnic groups. We obtained demographic, enrollment, prior performance data, and long-term outcome data from the state-wide database for all students of the 63 schools. The sample included 5,991 students with both 6th and 8th grade EoG test scores (2,961 treatment

students, 3,030 control students). We examined student baseline equivalence on their 6th grade EoG test scores, gender, and ethnicity and found no significant difference between the two conditions.

To evaluate the efficacy of ASSISTments for improving students' long-term mathematics achievement in 8th grade (Research Question 1), we conduct an intent-to-treat (ITT) analysis using two-level hierarchical linear regression models (HLM). The HLM was used to account for the clustering effect of the data (students were nested within schools). We modeled the mean differences in Grade 8 EoG scores (the long-term outcome) between students in treatment and control schools, controlling for the student's Grade 6 scores and other student- and school-level covariates to improve the precision of the impact estimate. To address Research Question 2, we added the analytical model with a cross-level interaction term of the school-level treatment variable and indicator of student subgroup and conducted a series of moderator analysis examining whether the ASSISTments had a differential impact on minority (e.g., Hispanic, Black) versus nonminority (White) students. Similar models were also used to estimate the effects of the intervention on the students with other policy-relevant background variables.

The results showed that there was a statistically significant difference between students in the treatment and control conditions in their 8th grade EoG test scores ($p = 0.011$, effect size Hedges' $g = 0.10$) with students from the treatment schools performing significantly better than those in the control group. The moderator analyses showed that the intervention benefited minority (non-White) students, who started with significantly lower 6th grade EoG scores, significantly more than majority (white) students ($p = 0.003$, Hedges' $g = 0.14$) and that the impact was stronger for Hispanic students than non-Hispanic students ($p = 0.014$, Hedges' $g = 0.13$). Overall, the results suggested that ASSISTments had a sustained long-term impact on students' math learning, even after one year of intervention implementation. The program also helped close the achievement gap among students of different ethnicity.

5 Conclusion and Future Work

Enhancing mathematics education is an imperative challenge, especially given the significant learning loss that has transpired during the pandemic in the past three years. In this paper, we presented the promising long-term effects from a rigorous efficacy study of 63 schools that evaluated the impact of the ASSISTments homework support program in diverse settings and implementation circumstances. Historically, when the policy relevant state standardized tests were used as an outcome measure, few studies demonstrated impact on student learning [5] and long-term effects were rarely detected. Therefore, the findings have strong implications for math interventions. The findings demonstrate the potency of the ASSISTments program and its value in promoting math learning in middle school, as well as the promise of leveraging ASSISTments, and similar AI-supported programs, to help overcome the academic setbacks caused by the pandemic. The team is continuing with benchmarking the effect sizes and further analysis of the data to explore the variation of effects for different populations and school settings and relationships between ASSISTments usage in Grade 7 and performance in Grade 8.

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