Access to Algebra I:
The Effects of Online Mathematics for Grade 8 Students

Spring 2012 SREE Conference Symposium Proposal
Abstract Body

Symposium Justification (Background/Context):

This symposium presents the design and results of the Access to Algebra I: Effects of Online Mathematics for Grade 8 Students study, a large-scale, randomized experiment conducted by the Regional Educational Laboratory—Northeast and Islands (REL-NEI).

The study (also known as the “Virtual Algebra” study) was designed to inform the decisions of policymakers who are considering using online courses to provide access to Algebra I in grade 8. Prior research shows that while eighth-grade Algebra I enrollments have increased over the past two decades, approximately 25% of the highest-achieving students do not have the opportunity to take the course in grade 8 (Loveless 2008; Walston and Carlivati McCarroll 2010). Additional analyses of data from the Early Childhood Longitudinal Study (ECLS-K; U.S. Department of Education, 2009) suggest that access is most limited in rural schools—24% of rural schools do not offer the course to eighth graders, and a larger proportion of high-achieving students in rural schools do not take Algebra I in grade 8 than in urban or suburban schools.

This study focused on broadening access for students considered to be “ready for algebra” in grade 8, but who attend schools that do not typically offer the course. The study tested the impact of offering an online Algebra I course on students’ algebra achievement at the end of eighth grade and on their subsequent likelihood of participating in an advanced course sequence in high school. The study was designed to respond to both broad public interest in the deployment of online courses for K-12 students and to calls from policymakers to provide students with adequate pathways to advanced coursetaking in mathematics (e.g. see National Mathematics Advisory Panel 2008).

The proposed symposium consists of three papers, each focusing on a different aspect of the study. The first paper describes the study design and measures; the second paper describes the online Algebra I course that was delivered in the study; and the third paper discusses the impact results.

Given that the methodological and implementation complexities associated with this randomized trial will be highly relevant to SREE participants, and that the final results will be published and available prior to the March conference, we believe that this project warrants a symposium session. We have planned the symposium to allow for in-depth presentations and discussions focused on the study’s design and measures, online algebra I course intervention and final results.

Paper 1: Virtual Algebra Study: Design and Measures

Jessica Heppen, Peggy Clements

Purpose / Objective / Research Questions / Focus of Study:
This paper describes the design of the study, and the measures and methods used to conduct it. A total of 68 middle schools in Maine and Vermont participated in the study. Schools in these states that did not typically offer a full section of Algebra I to grade 8 students as of the 2007/08
school year were eligible to participate. In spring 2008, prior to random assignment, all schools identified the rising grade 8 students they considered to be “algebra ready” (AR).

Random assignment of schools to condition occurred in summer 2008. Schools in the treatment group received the online Algebra I course to offer to their AR students during the 2008/09 school year. Schools in the control group did not receive the online algebra course during the 2008/09 school year and implemented their usual mathematics curriculum.

Outcome data were collected from two distinct student samples: 1) the 440 AR students who attended the participating schools, and 2) 1,445 “non-algebra ready” (N-AR) students who were in grade 8 in the participating schools in 2008/09, and had not been identified as “AR” the spring before random assignment.

The primary goal of the study was to measure the effects of offering an online Algebra I course to AR students in grade 8 in schools that do not typically offer the course. The primary research questions asked whether access to online Algebra I improves AR students’ knowledge of algebra in the short term and whether it opens doors to more advanced mathematics course sequences in the longer term. The specific primary research questions were:

1. What is the impact of offering an online Algebra I course to AR students on their algebra achievement at the end of grade 8?
2. How does offering an online Algebra I course to AR students affect their likelihood of participating in an advanced course sequence in high school?

The secondary goal of the study was to estimate potential unintended consequences (or side effects) of offering online Algebra I to AR students. Offering the online Algebra I course may affect these students in unintended ways. Taking the online Algebra I instead of general grade 8 mathematics may, for example, adversely affect AR students’ general mathematics achievement. Providing online Algebra I to AR students may also have unintended consequences for N–AR students—the students who remain in the general mathematics course. For example, when the AR students are removed from the general grade 8 mathematics class, student outcomes for the remaining students may be affected because of peer effects; smaller class sizes; a change in course emphasis (for example, less algebra); or other reasons.

Four secondary research questions examined these issues:

3. What is the effect of providing online Algebra I to AR students on their general mathematics achievement at the end of grade 8?
4. What is the effect of providing online Algebra I to AR students on the algebra achievement of N–AR at the end of grade 8?
5. What is the effect of providing online Algebra I to AR students on the general mathematics achievement of N–AR students at the end of grade 8?
6. How does offering an online Algebra I course to AR students affect the likelihood that N–AR students follow an intermediate course sequence in high school?
By answering the primary and secondary research questions, this study examined what happens to the entire population of grade 8 students—including potential benefits and possible negative consequences—when a school uses an online course as a way to offer Algebra I to AR students. The study thus informs decision makers who are considering investing in an online course as a means to broaden access to Algebra I in grade 8.

**Setting:**
The 68 schools that were randomly assigned were spread across Maine and Vermont. Sixty-two (91%) were classified as rural schools, as defined by the Common Core of Data. As of the 2007/08 school year, grade 8 enrollments ranged from fewer than 4 to 146 students, with average enrollment of 31. Fifty-two schools (76%) served grades pre-K–8 or K–8. Ten schools (14%) serve middle grades (grades 5–8, 6–8, or 7–8). The remaining six schools served other grade spans including K–12, 7–12, and 3–8. The students served in the participating schools were primarily White (95%). Nearly half (48%) were eligible for free- or reduced-price lunch and 53% scored at or above proficiency on the state mathematics assessments given the year prior to the study. There were no statistically significant differences in characteristics between the 35 schools in the treatment group and the 33 schools in the control group.

**Population / Participants / Subjects:**
The study included two samples of grade 8 students—AR students and N–AR students—in the 68 participating schools (Table 1, Appendix B). AR students represented 22% of the grade 8 students in participating schools. (An average of 6.5 AR students per school were identified prior to random assignment; in four schools, all grade 8 students were identified as AR.) The analytic AR sample included 218 students in treatment schools and 222 students in control schools. More than 96% of AR students in treatment schools (211 of 218) enrolled in the online Algebra I course for the 2008/09 school year.

(please insert Table 1 here)

The N–AR students were identified by collecting rosters of grade 8 mathematics classes from all study schools at the start of the 2008/09 school year. The analytic sample included 744 N-AR students in treatment schools and 701 N-AR students in control schools.

Table 2 in Appendix B summarizes the characteristics of students in the participating schools as of fall 2008. It shows baseline characteristics for the AR and N-AR samples overall (across conditions) and by condition. Differences between the treatment and control groups did not differ significantly from zero across measured demographic characteristics and prior mathematics achievement based on pre–random assignment data from the prior school year. However, there was a difference by condition on the study pretest, administered after random assignment in fall 2008. For this reason, the state mathematics assessment scores were used as the measure of prior achievement for the main analyses for the study.

(please insert Table 2 here)

**Intervention / Program / Practice:**
*Please see Paper 2.*
**Research Design:**
The study used an experimental design with random assignment of schools to treatment and control conditions within six state by size blocks, where size was determined on the basis of the eighth-grade student population.

The 35 schools assigned to the treatment group offered the online Algebra I course to their AR students. The 33 control schools did not receive the online algebra course during the 2008/09 school year. These schools offered business as usual mathematics instruction to both AR and N-AR students, which was expected to include varying amounts of algebraic content but not be a formal Algebra I course.

To estimate the impacts of online Algebra I on relevant outcomes for both AR and N–AR students, we compared outcomes for AR students in treatment schools with those for AR students in control schools. This comparison was designed to reveal the effects on students’ mathematics achievement, over time, of using an online course in order to broaden access to Algebra I for students who otherwise would not have access to a formal Algebra I course (not to compare an online Algebra I course to a face-to-face Algebra I course). To assess potential unintended consequences to the remaining students when a school offers an online Algebra I course, the study also compared N–AR students in treatment schools with N–AR students in control schools (Figure 1 in Appendix B).

(please insert Figure 1 here)

**Definition of a Successful Intervention**
The online Algebra I course was considered successful if the results showed both:

1) a statistically significant positive impact on either of the two primary research questions (AR students’ algebra scores at the end of grade 8 or high school coursetaking)

   and

2) the absence of statistically significant negative side effects (as assessed by the four secondary research questions).†

Only this combination of results would provide evidence that there are benefits of adopting an online Algebra I course for AR students without significant negative consequences to them or their N–AR peers.

**Hetereogeneity of Treatment Effects**

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* Schools in the control group received the online course for the 2009/10 school year. All schools (treatment and control) were provided the online course for two consecutive years.

† For the secondary questions, the study was not designed to determine whether the groups are statistically equivalent. A lack of statistical significance for an impact estimate does not mean that the impact being estimated equals zero. Rather, it means that the estimate cannot reliably be distinguished from zero, an outcome that may reflect the small magnitude of the impact estimate, the limited statistical power of the study, or both.
The study design and its associated analytic framework is an example to researchers interested in rigorously testing a more comprehensive set of impacts of education interventions – both potential benefits and costs – particularly when adoption of the intervention introduces ability tracking. The study explicitly acknowledged that the intervention may have varying effects on different types of students, in this case, students with varying incoming mathematics skills and readiness for a formal Algebra I course. Only students considered AR were offered the online course, but the allocation of the AR students to the course changes the regular class in measurable ways that could affect the N-AR students.

Data Collection and Analysis:
Data were collected in the study schools during the 2008/09 school year for all AR and N-AR students. In spring 2010, follow-up data on AR students’ coursetaking patterns were collected from the high schools they attended in grade 9. The study’s primary research questions were addressed with the following outcome measures:

- **Algebra Achievement.** Algebra achievement was measured with a computer-adaptive assessment administered to all AR and N-AR students at the end of grade 8. The algebra item bank contains approximately 300 items and yielded an IRT-based score for each student.

- **Participation in Advanced Courses.** Advanced coursetaking was measured by collecting and coding AR students’ actual grade 9 and planned grade 10 course information in spring 2010. Based on prior research on course sequences, the high school course data were coded as advanced if the students successfully completed a full-year course above Algebra I in grade 9 with a grade of C or higher, and enrolled in the next course in the sequence for grade 10.‡.

To address the secondary research questions, we also administered a general mathematics achievement test the end of grade 8 to all AR and N-AR students and collected planned ninth-grade mathematics course enrollment information (coded, for N-AR students, as indicating likely participation in an “intermediate” course sequence, or not).

The basic strategy for the impact analysis was to estimate the difference in outcomes between the treatment and control groups, adjusting for the blocking used in random assignment and for school- and student-level covariates.

Findings / Results:
*Description of the main findings with specific details.*
*Please see Paper 3.*

Conclusions:
*Description of conclusions, recommendations, and limitations based on findings.*
*Please see Paper 3.*

‡ E.g. Schneider, Swanson, and Riegle-Crumb (1998).
Paper 2: Virtual Algebra Study: Intervention Overview and Implementation Results

Peggy Clements, Kirk Walters, Cheryl Tobey

Intervention / Program / Practice:
This paper describes the online Algebra I course that was delivered as the intervention in this study. It is a completely web-based course offered by Class.com, based in Lincoln, Nebraska. The Algebra I course was one of Class.com’s existing products. As implemented for the study, the online Algebra I course had three instructional components: the online course software, an online teacher (provided by Class.com), and an on-site proctor (provided by the school).

Researchers determined that the topics covered in Class.com’s Algebra I course were similar to those in typical Algebra I textbooks used in the region. The material for each topic is presented in the form of an electronic, interactive textbook that consists of computerized direct instruction; guided practice (“your-turn” problems) and practice problem sets, both with automated feedback; and quizzes and exams that provide immediate scores. Other activities include demonstrations of content materials; audio clips; interactive applets that present questions and guided solutions; a messaging feature through which students can send and receive messages from the online teachers; and a discussion board to which students can post questions and comments.

Students taking the online course were assigned to a specific course section and taught by an online teacher hired, trained, and supervised by Class.com. The online teacher was responsible for providing instruction and supporting student learning.

Participating schools were required to provide a school staff member to serve as an on-site proctor, who would supervise and support students while they were using the online course. The proctor did not have to be a mathematics teacher and was not required to provide instruction. Proctors were expected to supervise students’ behavior, serve as a contact person for students and parents, proctor quizzes and exams, and act as a liaison between the online teacher and the school, students, and parents.

A total of 242 students enrolled in the online course (211 AR students and an additional 31 N–AR students placed into the course by their schools after random assignment). Students within schools were enrolled in one of 10 course sections, with an average of 24 students per section. All treatment schools met with the study’s requirement to provide the online course as the participating student’s mathematics course for eighth grade (that is, not as a supplemental course).

This paper includes a discussion of how implementation was measured in order to gauge treatment fidelity and the service contrast between treatment and control schools. Data were collected to document the implementation of the online Algebra I course in treatment schools. Analyses of archived data from the online course management system and data from weekly proctor logs were used to gauge the amount and type of interaction between students, online teachers, and in-class proctors. Archived course data were used to measure students’ progress in and completion of the course. In control schools, classroom materials were collected and analyzed to contrast the amount of algebraic content taught in the general grade 8 mathematics classes that did not offer the online Algebra I course.
**Paper 3: Virtual Algebra Study: Summary of Findings**

Ann-Marie Faria, Jessica Heppen, Kirk Walters, Nick Sorensen, Peggy Clements

**Findings / Results:**

This paper describes results concerning the impact of offering an online Algebra I course in schools that do not typically offer Algebra I, on student outcomes—primarily on AR students’ end-of-grade 8 algebra achievement and their subsequent likelihood of participating in advanced mathematics course sequences in high school.

The impact analyses for the primary research questions compared AR students in treatment schools (who were offered the online Algebra I course) with their counterparts in control schools (who were not offered the online Algebra I course and presumably took a general mathematics course). The impact analyses for research questions involving N-AR students compared N-AR students in treatment schools (where AR students were removed from the general class to take the online course) with their counterparts in control schools (where both AR and N-AR students were assumed to take a general mathematics course). All analyses of outcomes at the end of grade 8 were conducted separately for the AR and N–AR student samples; AR students were never compared with N–AR students.

Analyses of the algebra and general mathematics posttests used hierarchical linear modeling (Raudenbush and Bryk 2002), accounting for the nesting of students within schools and controlling for student- and school-level covariates. Results are reported both in their original metric and as effect sizes. The analyses of coursetaking sequences used hierarchical generalized linear models that assume a Bernoulli sampling distribution and logit link function (Raudenbush and Bryk 2002; McCullagh and Nelder 1998). These models, appropriate for use with binary outcomes, accounted for nesting of students within schools and included the same student- and school-level covariates as the models used for the achievement outcome measures. For binary outcomes, results are reported in terms of differences in predicted probabilities (of participating, for example, in an advanced course sequence) and odds ratios.

In addition to the main impact results, this paper will also describe the results of implementation analyses, including the extent to which participating students completed the course, the amount and type of interaction between online course participants and their teachers and proctors, and a contrasting of the course content with that of the mathematics courses offered in control schools.

All analyses are completed. However, the results cannot be shared at this time because the report is currently under final review in the Institute of Education Sciences. The final report is expected to be released fall of 2011, well before the spring SREE conference. (REL-NEI is under contractual obligation to the U.S. Department of Education’s Institute of Education Sciences to publish the final report prior to December 31, 2011.)

**Conclusions:**
The conclusions (and ensuing discussion with participants) will be informed by the forthcoming results of the study.
Appendix A. References


Appendix B. Tables and Figures

Table 1. Number of Schools and Students per Condition as of Fall 2008

<table>
<thead>
<tr>
<th>Item</th>
<th>Total</th>
<th>Treatment</th>
<th>Control</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of schools</td>
<td>68</td>
<td>35</td>
<td>33</td>
<td>a</td>
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<tr>
<td>Number of grade 8 AR students</td>
<td>445</td>
<td>218</td>
<td>227</td>
<td>0.670</td>
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<tr>
<td>Number of grade 8 N–AR students</td>
<td>1,554</td>
<td>782</td>
<td>772</td>
<td>0.800</td>
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<tr>
<td>Total number of grade 8 students</td>
<td>1,999</td>
<td>1,000</td>
<td>999</td>
<td>0.982</td>
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<tr>
<td>Average number of AR students per school (standard deviation)</td>
<td>6.54 (5.23)</td>
<td>6.23 (5.21)</td>
<td>6.73 (5.32)</td>
<td>0.698</td>
</tr>
<tr>
<td>Average number of grade 8 students per school (standard deviation)</td>
<td>31.94 (37.01)</td>
<td>31.00 (40.93)</td>
<td>32.94 (32.96)</td>
<td>0.830</td>
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</tbody>
</table>

AR is algebra ready. N–AR is not algebra ready.

Note: Sample includes 68 schools (35 treatment, 33 control) and 1,999 students (445 AR students, 1,554 N–AR students). AR students were identified before random assignment in June 2008. The sample of AR students does not include 23 students who moved during summer 2008; it does include 5 students who later refused to participate in the study. The number of N–AR students is based on information obtained from school rosters in fall 2008. The N–AR sample includes 63 students who later refused to participate in the study and 46 students who were later deemed “not testable” by their teachers and schools. Tests of significance were conducted using two-tailed χ² and independent sample t-tests.

a. Not applicable, because schools were allocated to treatment and control using a block randomized procedure.

Source: Records obtained from each school before random assignment (June 2008) and school rosters examined in fall 2008.

Table 2. Baseline Student Characteristics of Algebra-Ready and Non–Algebra Ready Student Samples at Random Assignment

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Overall</th>
<th>Treatment</th>
<th>Control</th>
<th>p-value</th>
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<tr>
<td><strong>AR students</strong></td>
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<tr>
<td>Percent eligible for free or reduced-price lunch (n = 436)</td>
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<td>Percent receives special education services (n = 437)</td>
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<td>Percent limited English proficient (n = 437)</td>
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<tr>
<td>Percent female (n = 440)</td>
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<td>Percent racial/ethnic minority (n = 440)</td>
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<td>Mean grade 7 score on state mathematics assessment (standardized) (n = 437)</td>
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<tr>
<td>Mean fall 2008 Promise Assessment pretest score (n = 435)</td>
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<td><strong>N–AR students</strong></td>
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<tr>
<td>Percent eligible for free or reduced-price lunch (n = 1,403)</td>
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<td>Percent receives special education services (n = 1,419)</td>
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<td>Percent limited English proficient (n = 1,419)</td>
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<td>Percent female (n = 1,439)</td>
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<td>Percent racial/ethnic minority (n = 1,438)</td>
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<td>Mean grade 7 score on state mathematics assessment (standardized) (n = 1,403)</td>
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<td>Mean fall 2008 Promise Assessment pretest score (n = 1,384)</td>
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</table>

Note: AR is algebra ready. N–AR is not algebra ready.

Sample includes 68 schools (35 treatment, 33 control); Full samples included 440 AR students (218 treatment, 222 control); and 1,445 N–AR students (744 treatment, 701 control); 4 control schools had no N–AR students. Student sample sizes vary for each row, based on the amount of missing data for each student characteristic.
Values are unadjusted. Differences in student characteristics by condition were tested using a model that accounts for the clustered data structure and blocking used for randomization. Figures in parentheses are standard deviations.

a. The model did not converge to produce estimates when controlling for five state by size dummy blocking variables. Reported \( p \)-value represents a model that controls for state and two dummy indicators for medium and large schools rather than their interactions.

b. State mathematics scores were standardized by using the mean and standard deviation of the test scores within each state, including only schools participating in the study. Data were missing for 3 AR students (1 from treatment schools, and 2 from control schools); data were also missing for 42 NAR students (23 from treatment schools, and 19 from control schools).

c. The Promise Assessment test was administered in the first month of the school year and is therefore not a pure pretreatment measure. Data were missing for 5 AR students (1 from treatment schools, and 4 from control schools); data were also missing for 61 N-AR students (30 from treatment schools, and 31 from control schools).

Source: Maine state department of education and Vermont supervisory unions; study records.

Figure 1. Framework for Estimating Impacts of Online Algebra I on Algebra-Ready and Non–Algebra Ready Students