ALEKS®

ALEKS at Big Bear Middle School:
Report on Efficacy Study Results
for the 2010-2011 School Year

Study of ALEKS at Big Bear Middle School

This study compared three groups of 8th Grade Algebra Readiness students at Big Bear Middle School (Big Bear Lake, CA) to determine which group performed better on the California Standards Test (CST) in General Math—those students using a traditional textbook or those students using the web-based, artificially-intelligent software program known as ALEKS. The Big Bear students taking the Algebra Readiness classes did not perform well enough on the 7th grade CST to enter Algebra in 8th grade and therefore took the Algebra Readiness course to prepare for Algebra I. The study revealed that the ALEKS students performed significantly better on the General Math CST than the students using the traditional textbook.

The following three groups of students from Big Bear Middle School were compared:

Control 1
(84) 8th graders who took Algebra Readiness during the 2008-09 school year

Control 2
(107) 8th graders who took Algebra Readiness during the 2009-10 school year

Experimental (ALEKS)
(100) 8th graders who took Algebra Readiness during the 2010-11 school year

For their 8th grade Algebra Readiness classes, the Control 1 and Control 2 groups learned via a traditional "lecture and practice" format using an Algebra Readiness (California edition) textbook. Practice was done using a workbook that comes with the textbook, and benchmark exams were given. Depending on the teacher, 50% to 75% of a student's grade was based on tests, and the rest was based on homework.

The Experimental group used ALEKS for the majority of its classroom instruction in an 8th grade Algebra Readiness class. About 90% of the student grade was based on work in ALEKS. When work was completed outside of ALEKS, it was small-group instruction facilitated by ALEKS progress reports. The mean amount of ALEKS use by a student for the school year was 71 hours (and the standard deviation was 11 hours).

Each of the three groups took the 7th grade CST the spring before taking the Algebra Readiness class and this became the baseline of our study. Each group also took the General Math CST during the spring while taking Algebra Readiness which enabled us to see the students' knowledge growth during the school year. Figure 1 shows a timeline and summary.

Figure 1: Timeline for the three groups: Control 1, Control 2, and Experimental (ALEKS)
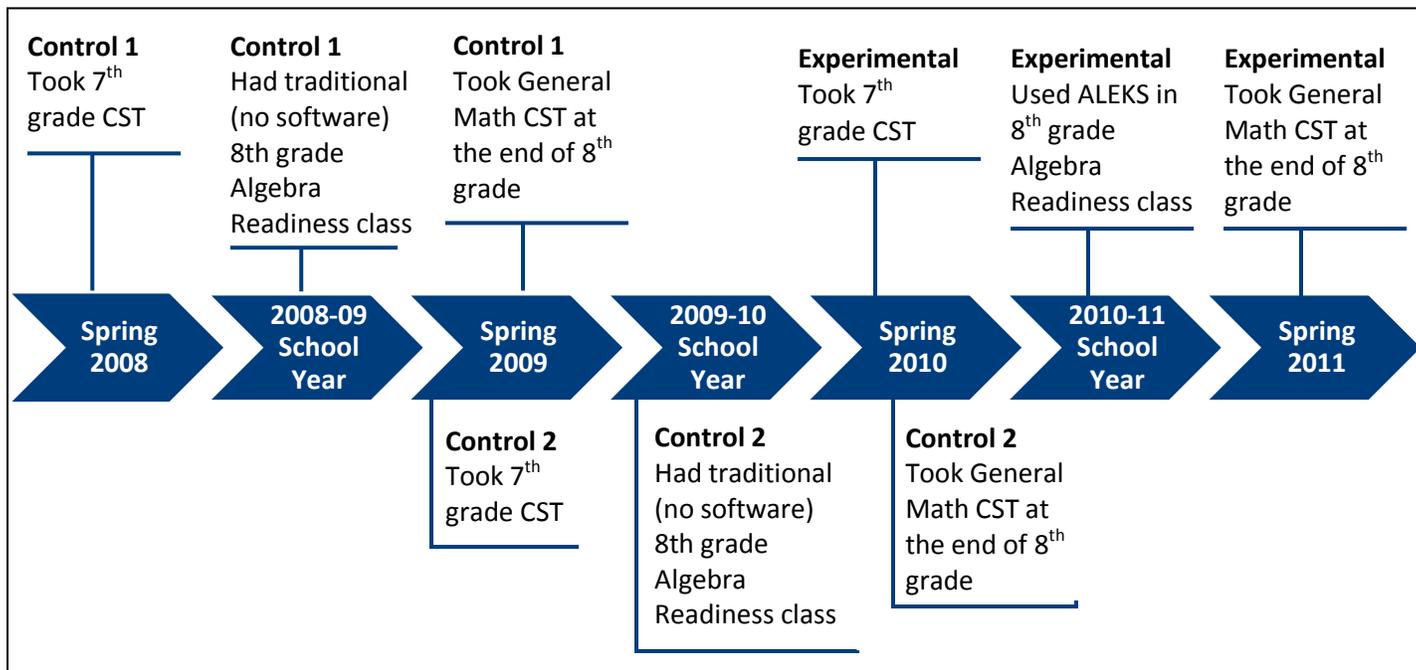
We note that three instructors taught the Experimental (ALEKS) group, but none of those instructors taught the Control 1 or Control 2 groups. As such, Control 1 and Control 2 are not true control groups; however, the data from these groups provide a solid comparison from which to examine the effectiveness of ALEKS. We chose to compare these three groups because of their significant similarities—all of the students in the study were placed in an Algebra Readiness class based on their low 7th grade CST scores, and all of the students took the 7th grade and General Math CSTs, thereby providing us with a measurement of learning growth between the beginning and end of the course.

What is ALEKS?

Assessment and **LE**arning in **K**nowledge **S**paces is a web-based, artificially-intelligent, continuously adaptive learning and assessment system that provides research-based, standards-aligned, rigorous content and utilizes diagnostic and progress monitoring assessments to inform instruction. The ALEKS system uses its proprietary artificial intelligence and adaptive questioning to assess quickly and accurately what a student knows and does not know in a course. Since ALEKS comprehensively determines the students' "knowledge state," that is, what they already know, and continuously updates that "knowledge state," students will not be forced into working on material they already know or material that is too difficult and for which they have not acquired the pre-requisite knowledge to learn successfully. ALEKS provides targeted and individualized instruction on the exact material that students are most ready to learn.

ALEKS avoids multiple-choice questions and instead uses flexible and easy to use answer input tools that mimic what would be done with paper and pencil. When a student first logs on to ALEKS, a brief tutorial shows her how to use these ALEKS answer input tools. The student then begins her completely individualized ALEKS Initial Assessment. In a short period of time (about 45 minutes for most courses), ALEKS assesses the student's current course knowledge by asking her a small number of questions (usually 20-30). ALEKS uses its unique artificial intelligence to determine the questions to ask next given the response the student has entered previously. Each student, and therefore each set of assessment questions, is unique.

The student's course knowledge is represented by a multicolor pie chart. The pie chart is also the student's entry into the Learning Mode. In the Learning Mode, the student is offered a choice of topics that ALEKS has determined she has the prerequisite knowledge to successfully learn. When she chooses a topic to learn, ALEKS offers her practice problems that teach the topic. These problems have enough variability that a student can only consistently answer them correctly after understanding the core principle defining the topic. If a student does not understand a particular problem, she can always access a detailed explanation for that exact problem. Once she can consistently provide the correct answer for a given topic, ALEKS adds the topic to the pie chart, and the student chooses another topic to learn. As the student learns new topics, ALEKS updates its map of the student's knowledge. The student can always observe the most current summary of what she knows and what she is ready to learn.

To ensure that topics learned are retained in long term memory, ALEKS periodically reassesses its students, using the results to adjust the students' knowledge of the course. Because students must show mastery through mixed-question assessments that cannot be predicted, mastery of the ALEKS course means true mastery of the course.

ALEKS, a Common Core and state-standards-based program, creates an environment of targeted, individualized learning, and as such, it is an instructional solution that can be used for traditional core or supplemental instruction, acceleration, intervention, and remediation.

Comparing the Progress of the Three Groups

Each student took the 7th grade CST the spring before taking the Algebra Readiness class, and each student took the General Math CST near the end of the Algebra Readiness class. The General Math CST and the 7th Grade CST are very similar. The tests scores are scaled from 150 to 600, and the two tests overlap in content—about 90% of the General Math CST covers material from the 7th grade CST. Despite this overlap, Big Bear students historically show a minimal increase in their scores from the 7th grade CST to the General Math CST. This is seen in the mean scores for Control 1 and Control 2 in the table below. In particular, the mean General Math CST score for Control 1 was only 12 points higher than the mean 7th grade CST

score; for Control 2, the mean General Math CST score was only 13 points higher than the mean 7th grade CST score.

Table 1: Comparing mean CST scores from 7th grade CST to General Math CST

	Mean 7th grade CST score	Mean General Math CST score	Increase from 7th grade CST to General Math CST
Control 1	330	342	12
Control 2	324	337	13
ALEKS	327	357	30

For the Experimental (ALEKS) group, however, the mean increased by 30 points from the 7th grade CST to the General Math CST, which was more than double the increase for each of the control groups. Note that the students in the Experimental (ALEKS) group came into their Algebra Readiness course with about the same average 7th grade CST score as their counterparts in Control 1 and Control 2; however, the Experimental group had a much higher average jump than their counterparts on the General Math CST.

The far-right column in Table 1 is depicted in Figure 2 below.

Figure 2: Increase in mean CST score from 7th grade CST to General Math CST
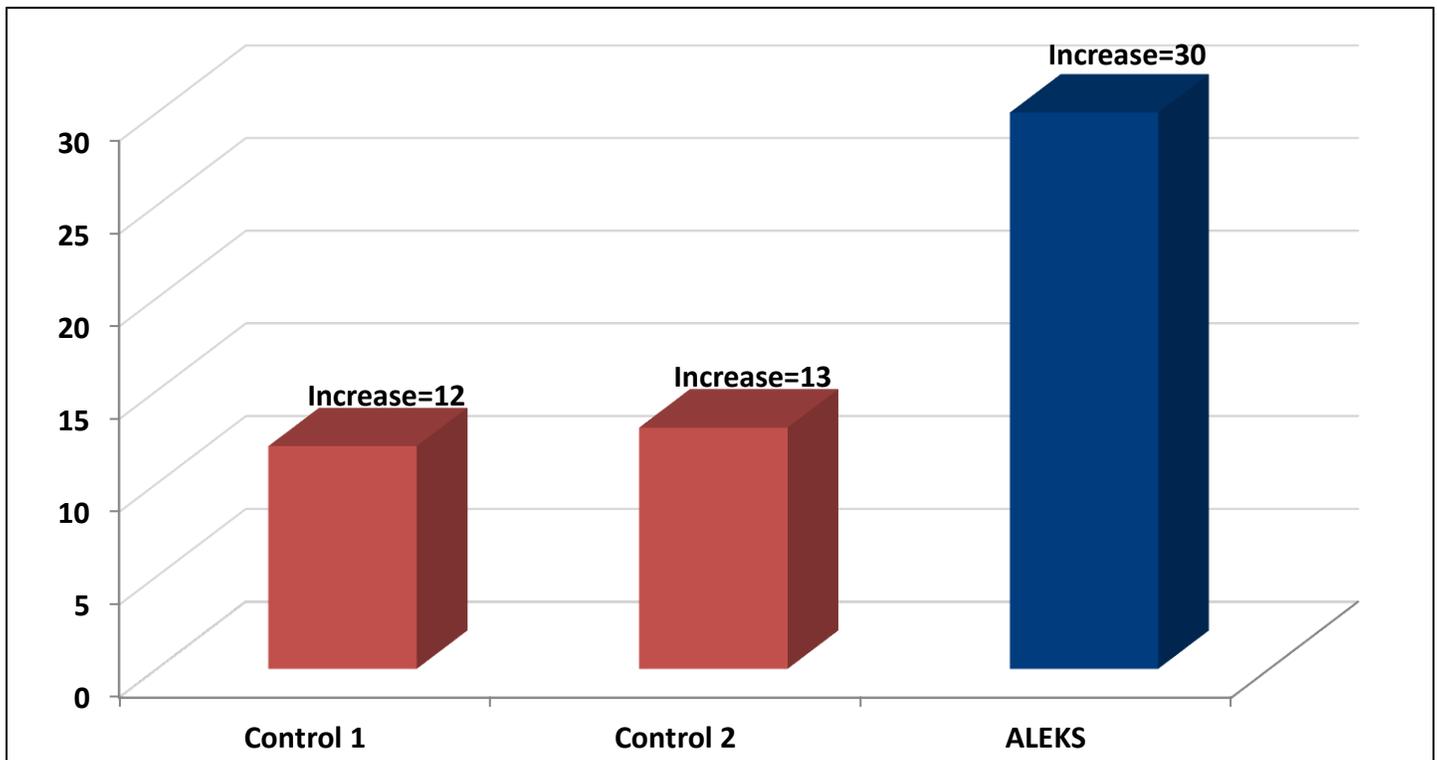
We note that the Experimental (ALEKS) group's mean General Math CST score showed a statistically-significant increase over each of the means from the control groups:

- For the Experimental (ALEKS) group, the mean was 357 and the standard deviation was 52.

- For Control 1, the mean was 342 and the standard deviation was 50.
  Doing a two-tailed t-test comparing the means of the ALEKS group and Control 1 gives a p-value of 0.042.

- For Control 2, the mean was 337 and the standard deviation as 46.
  Doing a two-tailed t-test comparing the means of the ALEKS group and Control 2 gives a p-value of 0.004.

In statistical significance testing, a p-value is the probability of obtaining a result at least as extreme as the one actually observed, assuming the conditions in the control and experimental groups are equal.

Consider the p-value of 0.042 for the test comparing the means of the ALEKS group and Control 1. This p-value means that, assuming the ALEKS students and Control 1 students were drawn from the same population and that the experimental conditions (use of ALEKS) had the same effect on CST scores as the control group's conditions, there is about a 4% chance of getting a difference in mean score at least as extreme as the one observed. Because this is a small percentage, we conclude that there was an effect of the experimental conditions, that is, we conclude that ALEKS had an effect.

Similarly, in comparing the Experimental (ALEKS) group and Control 2, there was about a 0.4% chance of getting a difference in mean score at least as extreme as the one observed. Again, we conclude that ALEKS had an effect.

Comparing "Proficient" and "Advanced" for the Three Groups

The California Department of Education states its goal as having all students classified as Proficient or Advanced on the CST tests: students scoring from 350 to 413 are classified as Proficient, and those scoring at least 414 are classified as Advanced.[1] For each of the three groups—Control 1, Control 2, and Experimental—we studied the percentage of students scoring Proficient or Advanced on the 7th grade CST and the percentage of students scoring Proficient or Advanced on the General Math CST.

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[1] California Department of Education Assessment Development and Administration Division. (January 10, 2012). "2011 STAR Test Results." Retrieved from http://star.cde.ca.gov/star2011/help_scoreexplanations.aspx

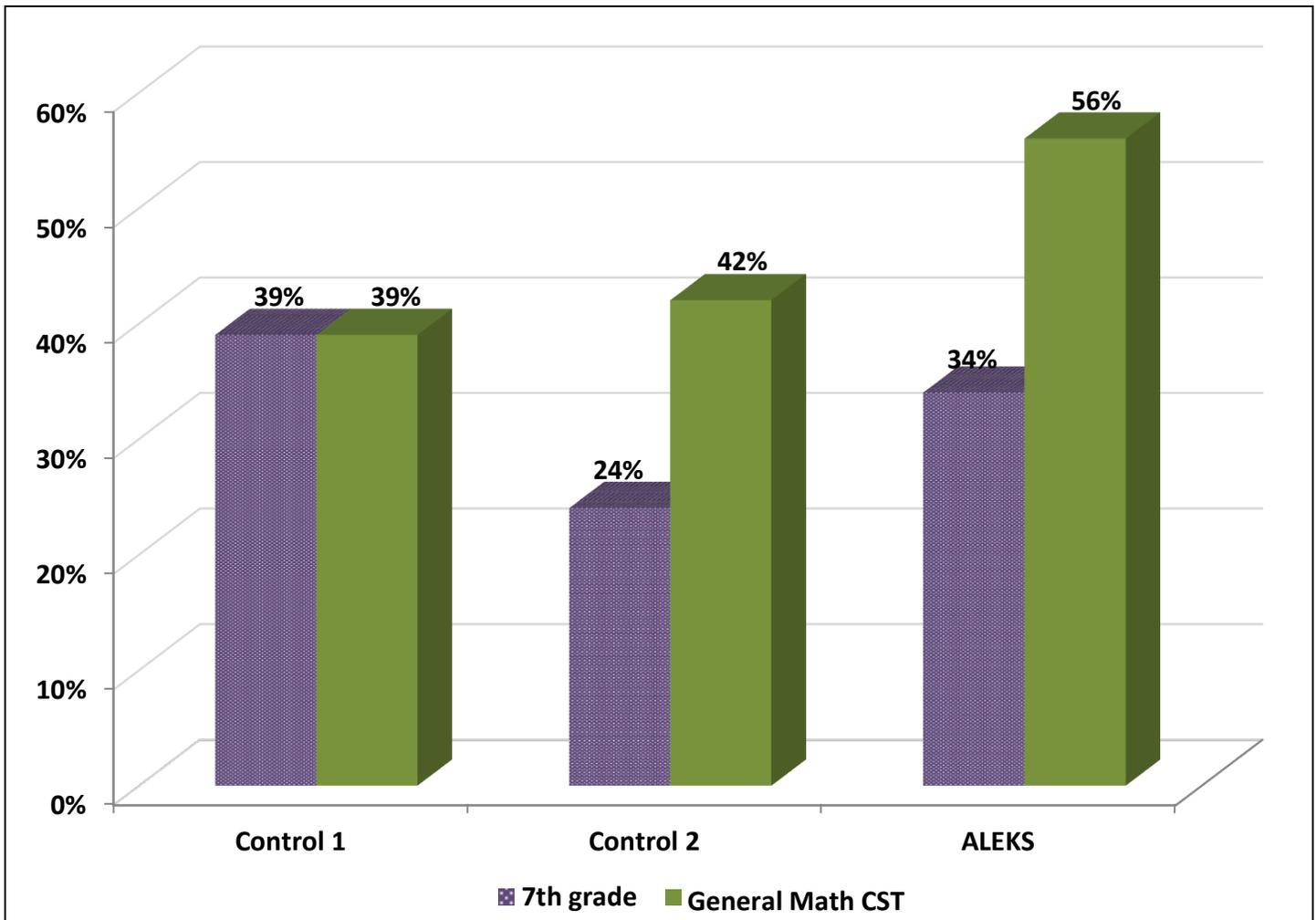**Figure 3: Percentage of students classified as Proficient or Advanced**

Figure 3 shows that:

- For Control 1, there was no change (39% to 39%) from the 7th grade CST to the General Math CST in the percentage of students scoring Proficient or Advanced.

- For Control 2, there was a sizeable jump of 18 percentage points (24% to 42%) from the 7th grade CST to the General Math CST.

- For the Experimental (ALEKS) group, there was also a sizeable jump, this time 22 percentage points (34% to 56%). Note also that the ALEKS group had the highest percentage of students scoring Proficient or Advanced.

Comparing Movement in Proficiency Category for the Three Groups

The CST has five proficiency categories: Far Below Basic, Below Basic, Basic, Proficient, and Advanced. With ALEKS, students were much more likely to move up in category from the 7th grade CST to the General Math CST and much less likely to move down than in Control 1 and Control 2 groups.

**Figure 4: Movement in proficiency category from 7th grade CST to General Math CST**
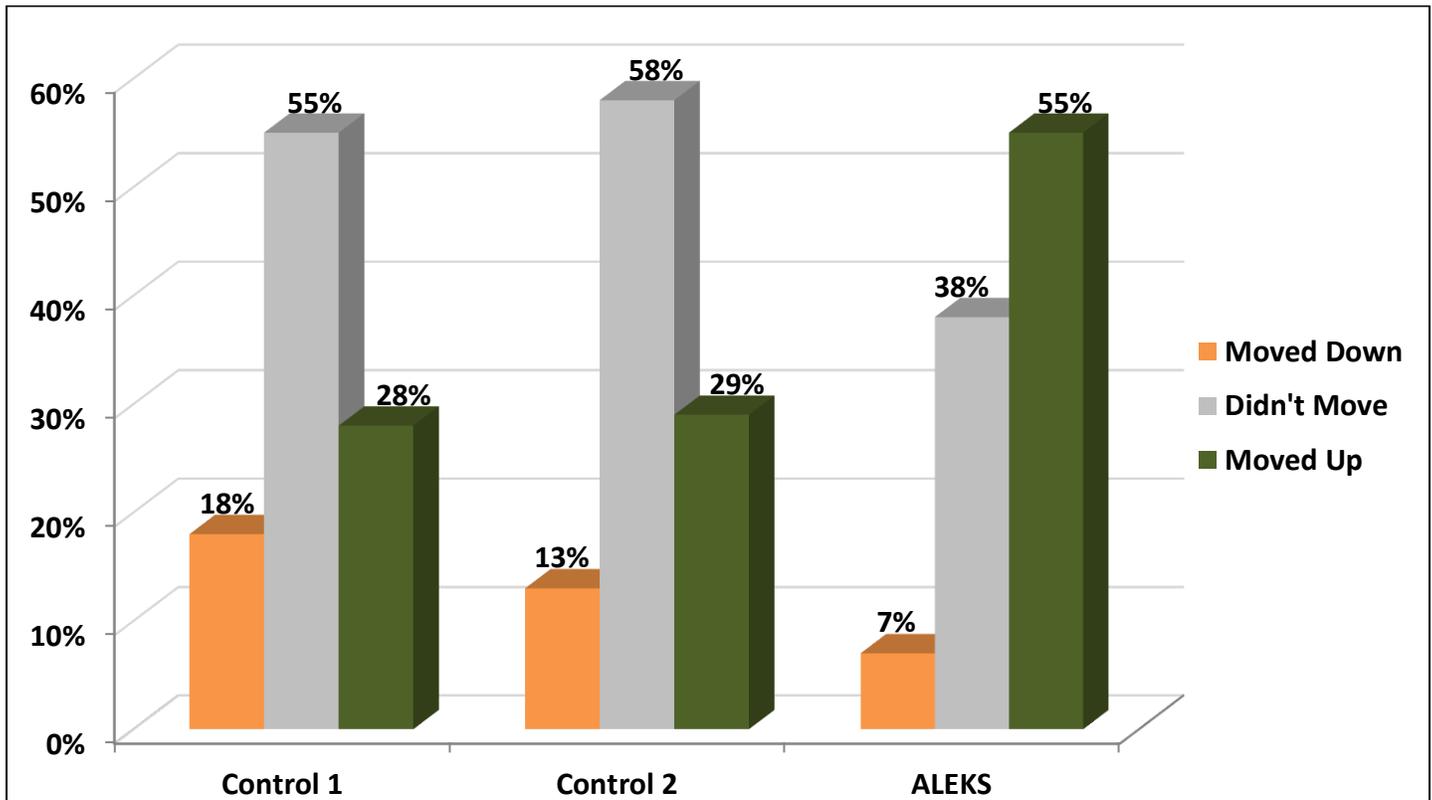
As shown in Figure 4, the results for Control 1 and Control 2 were quite similar for this measure, while the results for the Experimental (ALEKS) group were radically better. In particular, the ALEKS students were about twice as likely to move up in category than the Control 1 and Control 2 students, as shown by the dark green bars (55% for ALEKS versus 28% and 29% for Control 1 and Control 2, respectively). In addition, the ALEKS students were much less likely to move down in category than the Control 1 and Control 2 students, as shown by the orange bars (7% for ALEKS versus 18% and 13% for Control 1 and Control 2, respectively).

As mentioned, Big Bear Middle School students taking Algebra Readiness historically had improved their CST scores only minimally from the 7th grade CST to the General Math CST, and this is reflected in the scores for both control groups. The results shown in Figure 4 suggest that the Experimental group students, who are very similar to the students in the control groups, showed marked gains after using ALEKS.

Examining the Correlation between ALEKS and CST Scores

To the extent that an ALEKS knowledge state can better "predict" a CST score, ALEKS becomes a more useful diagnostic and learning tool. The graph below shows a high correlation, r=0.72, between the percentage of the ALEKS curriculum mastered (measured approximately as of two weeks before the General Math CST) and the 2011 General Math CST score for the Experimental group. This shows that ALEKS was a very good predictor of CST score.

Figure 5: CST score versus percentage of ALEKS curriculum mastered
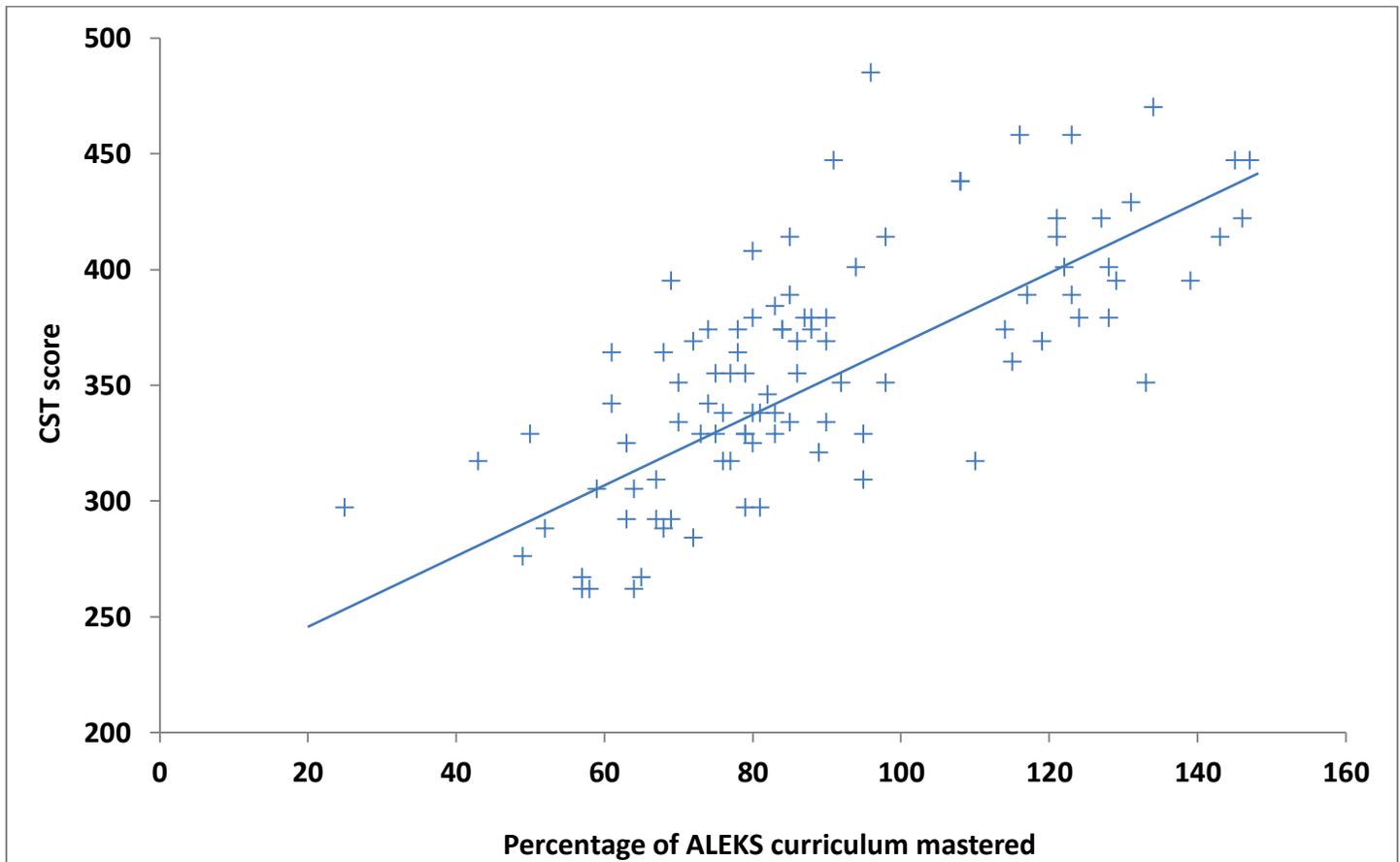
(Note that $r^2 = 0.49$, meaning that roughly half of the variation in CST scores, is accounted for by the percentage of the ALEKS curriculum mastered.) Some percentages in the graph are greater than 100 because some students completed the ALEKS Algebra Readiness curriculum and were moved into the ALEKS Algebra I curriculum.

Summary

The study examined three groups of students, one for each school year from 2008-2009 to 2010-2011. Two of the groups (Control 1 and Control 2) learned Algebra Readiness in 8th grade via a traditional (no software) format, and the third (Experimental) learned via ALEKS. Despite starting out with about the same mean 7th grade CST score, the Experimental (ALEKS)

group scored much better on the General Math CST than their counterparts in Control 1 and Control 2.

That the Experimental group scored better was seen in several ways: by the mean General Math CST score, by the percentage of students scoring Proficient or Advanced on the General Math CST, and by the improvement in proficiency category from 7th grade to General Math. Though Big Bear Middle School's Algebra Readiness students had historically shown little improvement from the 7th grade CST to the General Math CST (see especially Figures 2 and 4), students using ALEKS showed a significantly greater mean score increase (Figure 2) and a marked improvement in the proficiency category (Figure 4) over the historical population, giving strong evidence for the sizable effectiveness of ALEKS.

About ALEKS Corporation

ALEKS Corporation is a leader in the creation of web-based, artificially intelligent, educational software. ALEKS assessment and learning technologies were developed over several decades by researchers at New York University and the University of California, Irvine, through several projects funded by the National Science Foundation, and are derived from Learning Space Theory, a field of research in mathematical cognitive science.

Learning Space Theory is set forth authoritatively in Learning Spaces by Jean-Claude Falmagne and Jean-Paul Doignon (Springer-Verlag, 2011). This monograph is a revision and expansion of Knowledge Spaces (Springer-Verlag, 1999) and includes an examination of the mathematical basis for Learning Space Theory and its applicability to various practical systems of knowledge assessment (such as ALEKS). The mathematical areas used in Learning Space Theory are primarily Combinatorics, Probability, and Stochastic Processes. The research behind ALEKS is discussed briefly in non-technical terms in "The Assessment of Knowledge in Theory and in Practice," which is available at http://www.aleks.com/about_aleks/research_behind.

ALEKS has been used by millions of students in more than 50 academic subjects ranging from elementary school mathematics to PreCalculus at thousands of educational institutions throughout the world.

Our mission is to assist educators in dramatically improving learning outcomes through the delivery of superior and artificially-intelligent learning and assessment course products.

Additional information about ALEKS Corporation and the ALEKS products are available on our website at www.aleks.com.