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The Effects of a Traditional and Technology-based After-school Setting on 6th Grade Student's Mathematics Skills

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This study investigated the effectiveness of the Assessment and LEarning in Knowledge Spaces (ALEKS) system as a method of strategic intervention in after-school settings to improve the mathematical skills of struggling 6th grade students. Students were randomly assigned to after-school classrooms in which they either worked with ALEKS to improve their math skills or to classrooms where instruction was provided by certified teachers. Students' performance on the Tennessee Comprehensive Assessment Program (TCAP), administered annually to all Tennessee students, indicated that students assigned to the ALEKS condition performed at the same level as those taught by expert teachers (d =.09). Also, students participating in our after-school program outperformed non-participating students.

The need to improve mathematics education in the United States has been documented in several international and national studies. For example, the Program for International Student Assessment (National Center for Educational Statistics, 2009) reported that the performance of U.S. students in applied mathematical skills is not at the level of most of the 28 countries that participated. Although U.S. students possess many of basic mathematical skills, they lag behind their peers from other countries in their application of these skills to problems relating to higher level concepts such as space and shape, chance and relationships, quantity, and uncertainty. Results from national studies similarly demonstrate the need for mathematics improvement, particularly in the middle grades. The National Assessment of Educational Progress (NAEP), for example, reported that the percentage of students at or above the “proficient” level in mathematics was highest in fourth grade, decreased in eighth grade, and was lowest in twelfth grade (National Center for Education Statistics, 2008).

Technology is frequently assumed to have a positive impact on student learning in mathematics. This assumption has inspired the development of commercial technologies that target mathematics, such as MyMathLab (Pearson, 2011), and sophisticated intelligent tutoring systems, such as the Cognitive Tutors developed at Carnegie Learning (Heffernan, Koedinger, & Razzaq, 2008; Ritter, Anderson, Koedinger, & Corbett, 2007). Schacter (1999) reviewed over 700 empirical research studies in which students had exposure to computer-assisted instruction. The students showed overall positive gains in achievement on tests that spanned researcher-conducted tests, standardized state tests, and national tests. Regarding the intelligent tutoring systems (ITS), the effect sizes on experimenter-developed tests in assessments of intelligent tutoring systems are approximately 1.0 sigma compared to normal classroom teaching (Corbett, 2001). According to Ritter et al. (2007), standardized tests show overall effect sizes of 0.3 sigma in assessments in hundreds of classrooms, but perform particularly well for the subcomponents of problem solving and multiple representations, which show effect sizes of d = 0.7 to 1.2. The *What Works Clearinghouse* investigations show an effect size of 0.4 sigma according to Ritter et al. (2007). These large scale efforts present an optimistic picture of the role of technology in mathematics learning.

Nevertheless, the research on using technology to improve performance in mathematics has provided some mixed results when evaluated in the K–12 grades. Dynarski et al., (2007) reviewed software products for first grade reading, fourth grade reading, sixth grade math, and algebra finding no significant test score differences between the groups of students using the systems as part of their classroom instruction and the groups of students in standard classrooms. Similarly, the report of the National Mathematics Advisory Panel (2008) points to mixed results in the research on computer-based tutorials.

It could be argued, however, that ITSs should yield higher learning gains than traditional systems with computer-based training, multimedia, hypertext and hypermedia (Corbett, 2001; Dodds & Fletcher, 2004; Graesser, Chipman, & King, 2008; Graesser, Conley, & Olney, in press; Wisher, & Fletcher, 2004). Dodds and Fletcher's (2004) meta-analysis could help to reconcile the results reported by Dynarski (2007) and those reported in the ITS literature. Dodds & Fletcher (2004) reported effect sizes of 0.39 for computer-based training, 0.50 for multimedia, and 1.08 for intelligent tutoring systems. Dynarski et al. (2007) relied primarily on off the shelf products. While these products did include some intelligent tutoring systems such as Cognitive Tutor from Carnegie learning, the study primarily included Computer-based training (CBT) and multimedia systems with modest intelligence and adaptivity to individual students.

There are a large number of ITS's that target mathematics. Prominent examples include the Cognitive Tutors developed at Carnegie Mellon University for eighth grade algebra (Anderson, Corbett, Koedinger, & Pelletier, 1995; Koedinger, Anderson, Hadley, & Mark, 1997; Ritter et al., 2007) and geometry (Aleven & Koedinger, 2001) and the ASSISTment system that has a similar model-tracing computational architecture for web applications (Koedinger, McLaughlin, & Heffernan, 2010; Mendicino, Razzaq, & Heffernan, 2009). This study implements the intelligent tutoring system called ALEKS (Doignon & Falmagne, 1999).

ALEKS, a Mathematics Based Intelligent Tutoring System

ALEKS (Assessment and LEarning in Knowledge Spaces) is a Web-based learning system with artificial intelligence components. Its artificial intelligence is based on a theoretical framework called Knowledge Space Theory (KST) (see http://wundt.uni-graz.at/kst.php). KST allows the representation in the computer's memory of an enormously large number of possible knowledge states that organize a scholarly subject. Rather than giving a score or series of scores that describe a student's overall mastery of the subject, KST allows for a precise description of what the student knows, does not know, and is ready to learn next. According to KST, a subject such as arithmetic or Algebra I can be parsed into a set of problem types, with each problem type covering a specific concept (or skill, fact, problem-solving method, etc.). A student's competence can then be described by the set of problem types that the student is capable of solving. This set is called the student's *knowledge state*. A *knowledge space* is the collection of all of the knowledge states that might feasibly be observed in a population. Each mathematics subject matter typically has 250-350 problem types and several million knowledge states.

At the heart of ALEKS is the system's assessment engine. It attempts to uncover, by efficient questioning, the knowledge state of a particular student. The process usually takes from 25 to 35 questions that are given as a diagnostic test when the student starts using the system. This efficiency stems from the many inferences made by the system via the knowledge space.

At the beginning of a KST assessment, each knowledge state is given some initial probability. A question (problem type) is selected and based on the student's answer, the probabilities are updated. If the student answers correctly, then each knowledge state containing that problem type is increased in probability. If the student answers incorrectly, then each of those states is decreased in probability. The next question is selected according to an algorithm that is as informative as possible according to a particular measure. The process continues within a decision cycle until there is one knowledge state with a much higher probability than the others and this is the problem type assigned to the student.

ALEKS then provides, in the form of a pie chart and report, a summary of what the student knows, does not know, and is ready to learn (see Figure 1). The learner can then choose from among the problem types ready to be learned. Once the system determines that the problem type had been mastered, it is added to the student's knowledge state, and another problem type that is ready to be learned can be chosen. Subsequent assessments update the student's knowledge state.

The ALEKS system has some similarities to traditional CBT systems. It implements mastery learning where the learner (a) studies material presented in a lesson, (b) gets tested with a multiple choice test or another objective test, (c) gets feedback on the test performance, (d) restudies the material if the performance in (c) is below threshold, and (e) progresses to a new topic if performance exceeds threshold. The order of topics presented and tested follows a prerequisite structure where some skills need to be mastered before progress can be made on other skills. However, ALEKS moves beyond CBT by using Bayesian networks to adaptively select the next skill for a student to work on. The Bayesian networks of the knowledge space model attempts to fill learning deficits and correct misconceptions adaptively and dynamically (Doignon & Falmagne, 1999). It tracks the knowledge states of learners in fine detail and adaptively responds with assignments that are sensitive to these knowledge states.

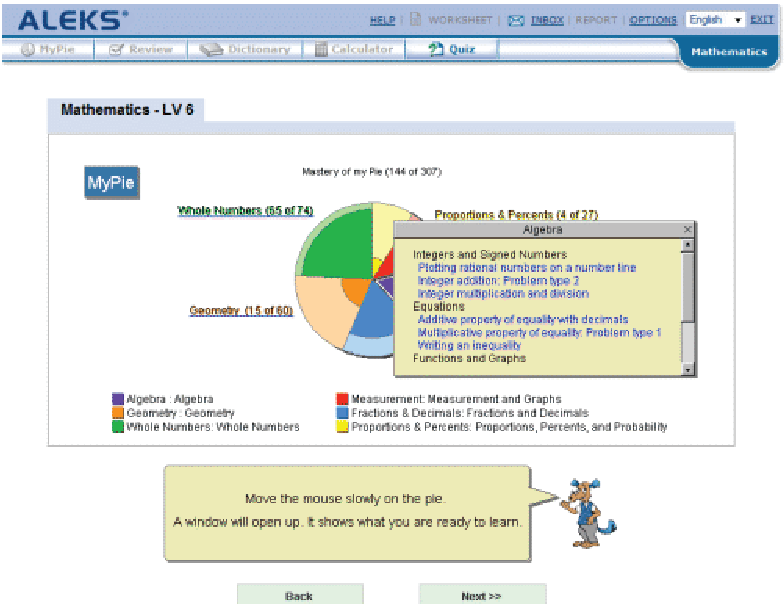

Figure 1. Screenshot of the ALEKS problem selection interface

ALEKS and the Tennessee Comprehensive Assessment Program

The validity of ALEKS assessments of mathematics proficiency has already been established in national studies and also in the targeted population of the present study. Regarding the latter, Sullins and colleagues (Sullins, Meister, Craig, Wilson, Bargagliotti, and Hu, in press) reported a strong relationship between ALEKS performance and Tennessee state test scores from the TCAP (Tennessee Comprehensive Assessment Program). Two separate studies investigated the relationship between students' interaction with ALEKS and mathematics achievement test scores. Study 1 included sixth, seventh and eighth graders enrolled in two mid-south urban school systems for a total of 218 students. Students participated in their normal curriculum as determined by their respective school and school system. In addition, they were given access to the ALEKS system. Results of a correlation analysis showed strong and statistically significant correlation (r = .84, p < .01, n = 216) between the TCAP scores and assessment performance in ALEKS. This result substantiates the claim that the ALEKS measurements are closely aligned with TCAP, the state standard for mathematics.

Study 2 was designed in order to partially replicate the results found in Study 1, but this time using a different school district and sample. As with the previous study, teachers used ALEKS as part of their regular mathematics instruction. Teachers allocated one day (usually Friday) each week as an "ALEKS day". Study 2 included 124 fifth graders, 98 sixth graders, and 99 seventh graders for a total sample of 321 students. Due to the lack of availability of TCAP scores, the final sample did not contain any individuals in grade eight. Results of the correlational analysis revealed a statistically significant positive correlation between performance in ALEKS and TCAP scores when all of the grades were combined ($r = .74$, $p < .0001$, $n = 321$). Once again, the ALEKS measures are aligned with the state standards.

Technology in classrooms versus after-school settings

As discussed earlier, some of the reports and research studies (National Center for Education Statistics, 2008; National Mathematics Advisory Panel, 2008; Dynarski, et al. 2007) incorporated technology in classroom settings and found no significant improvement. If Dynarski et al. is correct, the current state of learning technology has very little value added for classrooms. Therefore, it is plausible that replacing students' time in classrooms may not be the most effective use of technology for learning and other settings should be investigated. However, this would not imply that the technology is useless. Technology would be available when access to teachers is limited or nonexistent, yet resulting in no penalty in learning gains.

After-school settings provide an excellent time frame for the use of technology. Indeed, the additional time to devote to academic training of knowledge and skills is a learning opportunity for students for any subject matter and type of learning environment (Gayle, 2004; Kugler, 2001; Miller, 2003). However, this time is often underutilized with only around 11% of students participating in after-school programs (Kanter, 2001). The students attending these programs, particularly disadvantaged students, tend to be academically outperforming peers not in structured after-school programs (Vandell, 2007).

There is limited research that addresses mathematics practices in after-school settings directly (Lauer, Akiba, Wilkerson, Apthorp, Snow, & Martin-Glenn, 2003). Available research confirms that after-school programs have shown positive effects for math (Fashola, 1998; Lauer, Akiba, Wilkerson, Apthrop, Snow, & Martin-Glen, 2006). Vandell (2007) noted sixth and seventh grade students who regularly attended afterschool programs scored

12 percentile points better in mathematics than their peers. These results were again confirmed by a meta-analysis by Lauer (2003) who reported that it was after school programs that applied one-on-one tutoring techniques that displayed the greatest gains. However the effects of after-school programs are often murky because attendance in after-school programs tends to be sporadic and many students view the programs as additional school time (Vandell, Reisner, Brown, Dadisman, Pierce, Lee & Pechman, 2005).

The Current Study

This study reports Year 1 results of a three-year afterschool mathematics program that aims to help students in 6th grade from a west Tennessee school district improve student achievement in mathematics. A randomized experiment compared the ALEKS intelligent tutoring system to a condition with human tutors. This paper addresses two major research questions. First, how does computer mediated learning from ALEKS compare to learning from a human teacher in an after-school setting when assessing student achievement on the Tennessee Comprehensive Assessment Program (TCAP)? Second, how does the after-school program compare to students not included in the program in raising student achievement on TCAP?

METHODS

Participants

The participants were recruited for the after-school program from four intermediate schools in a school district in west Tennessee. The district serves both a mid sized city and the surrounding county with 13,607 students in grades Pre-K–12, distributed among 28 schools. The school system has a largely economically disadvantaged population (68.2%) and a minority student enrollment (56.3% African American, 3.4% Hispanic, 39.3% White, and 1% other).

The participants were 266 sixth grade students. There were 150 female students in the program and 116 males. The ethnicity breakdown was 202 African American students, 54 Caucasian students, and 10 other race students. We collected information on the students' gender, racial/ethnic background, and TCAP scores from 5th grade and 6th grade.

Materials and Assessment

Instructional content. In both conditions the information taught was guided by state performance indicators (SPIs). The indicators are topics that each student is expected to have mastered by the end of the year based on grade-level (See Appendix A). In ALEKS, the method of incorporating the SPIs is as simple as selecting the topics when creating the class in the program. However, in the teacher-led condition daily lesson plans were created by a mathematics education expert and an expert teacher, who were both members of the research team (See Appendix B for example lesson plan). Unlike ALEKS, which uses the individualized learning plans, for the teacher-led condition, if a student missed a day they would not receive instruction on that topic.

Assessments. For both the ALEKS and Teacher conditions the outcome measure of performance was the TCAP. This assessment is given at the end of each year for grades 3-8 to all students in Tennessee. It is the test used to evaluate the level at which each student has learned the SPIs for that year. The scores of the 5th grade TCAP were used to assess students' pre-program mathematics knowledge whereas the scores of the 6th grade TCAP were used as the posttest.

The state of Tennessee modified the testing requirements between the 2009 and the 2010 TCAP. This resulted into two primary changes. First, the TCAP proficiency levels change, as displayed in Table 1. The 2010-TCAP modification also included advanced topics requiring 6th grade students to know math topics that were previously on 7th and 8th grade tests. These changes in TCAP assessments reflected attempts to have the state of Tennessee be more aligned with national standards of NAEP.

Table 1

Proficiency levels on 2009 and 2010 TCAP

	Below Basic	Basic	Proficient	Advanced
Proficiency levels 2009 TCAP	500-658	657-711	712-751	752-900
Proficiency levels 2010 TCAP	600-702	703-754	755-790	790-900

Procedures

Recruitment and retention. To recruit participants in the after-school program, the research team visited the school during an assembly of the 6^{th} grade class. The first recruitment effort was directed specifically at students who scored in the lower 40th percentile of the TCAP in their 5th grade year. Subsequent efforts were open to all students. These efforts included flyers, teacher announcements, and other public notices directed towards parents.

To encourage attendance of students, a point-based incentive program was used. Students who attended the program were awarded points based on level of attendance (5 points for a full day and 3 points for a partial day). At the end of the program, the students could spend their accumulated points on various prizes (notebooks, book lights, small toys, scientific calculators, etc.). Those students who achieved very high attendance were entered into drawings for either a laptop (>90%) or an iPod nano (>80%).

Teachers certified to teach 6th grade mathematics by the state were recruited to conduct the after-school program. Teachers were paid at a rate of $25 per hour. Four teachers were assigned to a school different from their home school to eliminate crossover effects from interactions during the school day. After teachers were assigned to schools, they were randomized into either treatment or control classrooms.

Training on the procedures for both conditions was given to the teachers as a group prior to the program beginning. This was a one time session that lasted 4 hours. During this training, teachers were provided an overview of the program, training on how to use the ALEKS system and the lesson plans, a description of how ALEKS and the lesson plans were linked to state performance indicators, and the time schedule of the program. Teachers did not know their assigned role until after the training.

Each school also had an onsite facilitator that was appointed by the school's Principal. These positions were implemented during the second month of the program at the insistence of the Principals who wanted more oversight of the program at the local level (e.g. enforcement of schedules, placement of students into correct classrooms, and overseeing snack breaks) and more assistance to the teachers in dealing with student issues (e.g. discipline issues and removal of students from the program). Facilitators also handled any distribution of materials such as fliers during the school day. They were paid at a rate of $25 per hour for the hours of the after school program, but not for work during the school day.

Implementation. The after-school program was divided into two groups: the ALEKS group (treatment) and the teacher-led group (control). At each school there were four classes: two ALEKS and two control, with one teacher in charge of each class. Class size was capped at 25, which accommodated room for 100 students at each school.

In the ALEKS condition, students were tutored using the ALEKS program while in the control condition students were taught as a class by the teachers. In the ALEKS condition, teachers took on the role of supervisor providing help with technical issues with the computer and minimal mathematics help.

The program was held after school for two hours twice a week. The two hour periods included three 20 min tutoring sessions dived by two 20 min breaks with 10 min at the beginning and end for set-up and dismissal. During the first 20 min break students were provided with district approved snacks and in the second break student were allowed to play games. During the 20 min tutoring sessions, students in the ALEKS condition interacted with the ALEKS system during all three sessions. In the control condition, students were taught using the *I do-We do-You do* technique. This technique has three sessions. In the first session the teacher provided math problems and worked through them. In the second, the class worked on transfer activities as a group, whereas in the third the students worked through new problems on their own. Every fifth day a short assessment on recent material was given in both conditions to evaluate progress.

Data Analysis

Data were collected from the district and from the ALEKS program. The district provided background characteristics (gender and racial/ethnic background) of each student as well as student TCAP scores from both 5th grade (before the program, TCAP 2009) and 6th grade (after the program, TCAP 2010). The ALEKS program collected information as to how often students attend. Each teacher in the Teacher condition and each monitor in the ALEKS condition kept student attendance throughout the duration of the program.

For both the ALEKS and Teacher conditions, the outcome measure of performance was the TCAP score in mathematics. The scores of the 5th grade TCAP were used to assess students' pre program mathematics knowledge whereas the scores of the 6th grade TCAP were used as the posttest.

To compare the effectiveness of the ALEKS condition with the Teacher condition (research question 1), we use student performance on the 6th grade TCAP as a dependent variable. As a first mode of analysis, we merely compare the mean scores on the 6th grade TCAP for the two groups using a t-test. We also estimated the following model:

$$Y_i = a + x_i^T b_1 + z_i^T b_2 + g_i^T b_3 + e_i$$

where x_i^T is a row vector of student characteristics (student score on the 5th grade TCAP, student gender, and student racial/ethnic background). The b_1 designates the associated column vector of coefficients, the z_i^T row vector indicates whether or not the student was in the ALEKS condition, and the b_2 designates the associated coefficient. The g_i^T expression is a row vector accounting for the student's attendance in the program, along with b_3 as the associated coefficient. To estimate the linear model, we used simple ordinary least squares (OLS). We also estimated several interactive models to gauge whether particular ethnicities or genders showed favorable benefits to being in one of the two types of instructional conditions. However, none of the interaction terms proved significant, so we are only presenting the linear model.

To answer the second research question and gauge whether participation in the after-school program is associated with higher math achievement, we include all 6th grade students from the four schools in our sample and estimate the following model:

$$Y_i = a + x_i^T b_1 + f_i^T b_2 + e_i$$

where x_i^T is again a row vector of student characteristics with b_1 designating the associated column vector of coefficients, the f_i^T row vector indicating whether or not the student was participating in the program, and with b_2 being the associated coefficient.

RESULTS

Students in both conditions together scored an average of 488 out of 900 the TCAP exam prior to entering the program, which is at the lowest TCAP category. At the end of the program these scored an average of 707 or Basic understanding level. These results are a promising confirmation that the afterschool program was effective.

Table 2 shows the descriptive statistics by condition. A t-test conducted on students' 5th grade TCAP performance did not indicate any significant differences between conditions, with mean scores of 489 and 487 in the ALEKS and Teacher conditions, respectively, $t(272) = 0.53$, $p = .297$. A *t*-test conducted on students' 6th grade TCAP performance comparing the ALEKS versus Teacher conditions showed no significant differences between the groups, with corresponding means of 711 and 702, $t(262) = 0.74$, $p = .23$, $d = .09$. The scores were in the predicted direction but not significant statistically.

Table 2

Means and standard deviations for 2009 and 2010 TCAP by condition

	ALEKS		Teacher	
	M	SD	M	SD
2009 TCAP scores	488.96	27.44	487.28	24.70
2010 TCAP scores	711.01	94.72	702.33	98.19

Table 3 presents the multiple regression results for the students who participated in the program. This analysis predicted 29% of the observed variance for students 6^{th} grade TCAP scores, $R^2 = 0.292$; $F(6, 257) = 17.71$, $p < .00$. The results revealed higher scores on 6^{th} grade TCAP (2010) were predicted by 5^{th} grade TCAP scores, student gender, and students with higher attendance, whereas race and experimental treatment were not significant.

A separate multiple regression analysis was conducted on students 6^{th} grade TCAP performance to determine if there was an impact for the program overall as compared to the overall population. This analysis significantly predicted 35% of the variance, $R^2 = .354$, $F(5, 793) = 86.75$, $p < .00$. Table 4 shows that participation in the program was significant at the .10 level in increasing achievement. A caveat to this result is that students not only volunteered to participate in the study but also were free to drop out when they wish to. Therefore, the comparison of participation in the program versus not participation in the program cannot be interpreted as causal. Nevertheless, the added value of participation in the after-school program is encouraging.

DISCUSSION

In general, our study replicated some of the previous findings in the literature. Overall, students in our afterschool program performed better in mathematics than peers not in our program, which is consistent with Vandell (2007) and Lauer et al. (2003). As stated earlier, attendance in the program was a significant predictor of performance for students in our program. It is not surprising that attendance was such a strong predictor. Other studies have shown similar links. Previous work by Vandell et al. (2005) found that for good quality after school programs, regular attendance was associated with better work and study habits in students.

Table 3
Multiple Regression Analysis on 6th grade TCAP scores for students in the after-school program

Predictor Variable	Unstandardized Coefficients	SE	M	SD
2009 TCAP score	1.91***	0.2	487.56	26.10
ALEKS treatment	7.92	10.313	0.49	0.50
Male	-22.23**	10.391	0.44	0.50
Black	-7.45	13.018	0.77	0.42
Other	2.67	31.92	0.03	0.17
Attendance	0.16**	0.08	93.71	65.00
Constant	-230.91**	100.643		

N = 264
R-squared = 0.292
*** p<0.01, ** p<0.05, * p<0.1

Table 4
Multiple Regression Analysis on student 6th grade TCAP for the program compared to non-program students

Predictor Variable	Unstandardized Coefficients	SE	M	SD
2009 TCAP score	1.54***	0.081	505.61	34.99
Program	10.92*	5.838	0.34	0.47
Male	-12.38**	5.158	0.52	0.50
Black	-6.83	5.862	.64	0.48
Other	-12.92	12.493	.05	0.21
Constant	-44.73	42.987		

N = 799
R-squared = 0.354
*** p<0.01, ** p<0.05, * p<0.1

The current study provides collaborating evidence from mathematics for Frankel Streitburger, and Goodman's (2005) claim that students attending after-school programs regularly showed greater academic achievement than those who attended less frequently. A simple explanation of time on task readily explains these results. Although the results are not terribly surprising, the finding is informative to the extent that attendance in after-school programs tends to be sporadic (Vandell et al., 2005). As can be seen from the standard deviation term for attendance in Table 3, the current study had a wide range of attendance among the participants.

Students participating in our afterschool project performed better than peer students not enrolled in our program. When looking at the 5th grade TCAP means, our subject population was below the scale rankings, not even reaching the lowest cutoff score of 500. In contrast, students participating in our program increased two categories on average to the basic level. So, it appears that both of our after-school programs (ALEKS and Teacher conditions) were helpful to our students.

We found that students in the ALEKS condition had mean scores that were equal or higher (but not statistically significant) than the teacher-led condition on TCAP scores after the intervention. This result is compatible with the Dynarsky et al (2007) study that reported a small effect of computer technologies compared to the classroom teaching. His study reported a net effect size advantage for technologies of $d = 0.05$, which is close to the $d = 0.09$ value of our study. The good news is that the computerized intervention did not lower performance.

It could be argued that the quality of the instruction in the Teacher condition was higher than that of most teachers. The curriculum for the afterschool program in the Teacher condition was created by our mathematics education experts and implemented by certified and highly experienced teachers who had been exposed to ALEKS. We adopted the effective "I do, we do, you do" methods that is known to be effective in teach mathematics. In addition, due to small classes in the after-school program, some of the Teacher led groups had a very small student-teacher ratio, which gave advantages to the Teacher condition. Nevertheless, the ALEKS condition had an effect size advantage of .09 over the Teacher condition, which was not statistically significant but encouraging.

Overall, the first year of the program was successful and provided many lessons for future years. While statistical differences between conditions were not observed in year one, the overall improvement of students in the program compared with peers not enrolled in the program indicates that the program could have two equality effective programs. Students in the ALEKS conditions did lean to outperforming students in the Teacher condition and did outperform students in non-program conditions. If these trends continue in future years of the program, significant levels could be reached.

But if current trends continue, then we could have two highly effective after-school mathematics programs for school systems to choose from based on their individual needs.

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APPENDIX A

Session	Objective	Grade Level Expectation	SPI
1	TSW use area models to represent multiplication of fractions	GLE 0606.2.1 GLE 0606.1.4	SPI 0606.2.1
2	TSW create and solve contextual problems that lead naturally to division of fractions	GLE 0606.2.1 GLE 0606.1.2	SPI 0606.2.1
3	TSW solve problems involving the addition and subtraction of fractions and mixed numbers and will explain the procedure used	GLE 0606.2.1 GLE 0606.1.2	SPI 0606.2.2
4	TSW solve problems involving the multiplication and division of fractions and mixed numbers and will explain the procedure used	GLE 0606.2.1 GLE 0606.1.2	SPI 0606.2.2
5	TSW solve problems involving the addition and subtraction of decimals and will explain the procedure used	GLE 0606.2.1 GLE 0606.1.2	SPI 0606.2.4
6	TSW solve problems involving the multiplication and division of decimals and will explain the procedure used	GLE 0606.2.1 GLE 0606.1.2	SPI 0606.2.4
7	TSW convert between fractions and decimals	GLE 0606.2.4 GLE 0606.1.4	SPI 0606.2.5
8	TSW convert between fractions and decimals	GLE 0606.2.4 GLE 0606.1.4	SPI 0606.2.5
9	TSW convert between fractions and decimals	GLE 0606.2.4 GLE 0606.1.4	SPI 0606.2.5
10	TSW convert between fractions, decimals, and percents	GLE 0606.2.4 GLE 0606.1.4	SPI 0606.2.5
11	TSW solve problems involving ratios, rates, and %	GLE 0606.2.3 GLE 0606.1.4	SPI 0606.2.6
12	TSW solve problems involving ratios, rates, and %	GLE 0606.2.3 GLE 0606.1.4	SPI 0606.2.6
13	TSW use concrete, pictorial, and symbolic representation for integers	GLE 0606.1.4 GLE 0606.2.5	SPI 0606.1.3
14	TSW use concrete, pictorial, and symbolic representation for integers	GLE 0606.1.4 GLE 0606.2.5	SPI 0606.1.3
15	TSW solve one-step inequalities corresponding to given situations and represent the solution on a number line	GLE 0606.3.5 GLE 0606.1.4	SPI 0606.3.1
16	TSW use order of operations and parentheses to simplify expressions and solve problems	GLE 0606.3.3	SPI 0606.3.2
17	TSW model the commutative, associative, and distributive properties to show that two expressions are equivalent	GLE 0606.3.5 GLE 0606.1.4	SPI 0606.1.4
18	TSW use equations to describe simple relationships shown in a table or graph	GLE 0606.3.1 GLE 0606.1.5	SPI 0606.3.3
19	TSW write equations that correspond to given situations	GLE 0606.3.1	SPI 0606.3.5

20	TSW model algebraic expressions using algebra tiles	GLE 0606.1.8	SPI 0606.1.5
21	TSW rewrite expressions to represent quantities in different ways	GLE 0606.3.2	SPI 0606.3.4
22	TSW translate between verbal expressions/sentences and algebraic expressions or equations	GLE 0606.3.5	SPI 0606.3.5
23	TSW solve one-step linear equations using the algebra tiles	GLE 0606.1.8	SPI 0606.3.6
24	TSW solve two-step linear equations using the algebra tiles	GLE 0606.3.1 GLE 0606.1.8	SPI 0606.3.6
25	TSW solve two-step linear equations using number sense, properties, and inverse operations	GLE 0606.3.1	SPI 0606.3.6
26	TSW write and solve two-step linear equations corresponding to given situations	GLE 0606.3.1	SPI 0606.3.6
27	TSW use algebraic expressions and properties to analyze numeric and geometric patterns	GLE 06060.3.4	SPI 0606.3.7
28	TSW select the qualitative graph that models and contextual situation; TSW write a contextual story modeled by a given graph	GLE 0606.3.5	SPI 0606.3.8
29	TSW graph ordered pairs of integers in all four quadrants of the Cartesian coordinate system	GLE 0606.3.6	SPI 0606.3.9
30	TSW generate data and graph relationships between two quantities	GLE 0606.3.5	SPI 0606.3.9
31	TSW explore basic properties of triangles and quadrilaterals using a protractor and ruler	GLE 0606.4.1	SPI 0606.4.1
32	TSW classify triangles by side lengths and angle measure	GLE 0606.4.1	SPI 0606.4.1
33	TSW investigate the sum of the angles of a triangle and a quadrilateral using various methods	GLE 0606.4.1	SPI 0606.4.2
34	TSW find a missing angle measure in problems involving interior/exterior angles and/or their sums	GLE 0606.4.1	SPI 0606.4.2
35	TSW model and use the Triangle Inequality Theorem	GLE 0606.4.1	SPI 0606.4.3
36	TSW relate the area of a trapezoid to the area of a parallelogram and solve problems involving the area of trapezoids	GLE 0606.4.3	SPI 0606.4.1
37	TSW develop and use formulas to determine the circumference and area of circles	GLE 0606.4.3	SPI 0606.4.4
38	TSW solve contextual problems involving area and circumference of circles	GLE 0606.4.3	SPI 0606.4.4
39	TSW determine the surface area of prisms and cylinders	GLE 0606.4.4	SPI 0606.4.5
40	TSW determine the volume of prisms and cylinders	GLE 0606.4.4	SPI 0606.4.5
Extra Lesson 1	TSW determine the surface area of pyramids and cones	GLE 0606.4.4	SPI 0606.4.5
Extra Lesson 2	TSW determine the volume of pyramids and cones	GLE 0606.4.4	SPI 0606.4.5

APPENDIX B

J-MITSE CONTROL

LESSON PLAN

SESSION 25

Objective: TSW solve two-step linear equations using number sense, properties, and inverse operations.

Part I – Direct Instruction – 20 minutes

Introduction- connection between solving one-step linear equations and two-step linear equations.

A *two-step equation* is an equation with two operations. You can use *inverse operations* to solve equations that have more than one operation. What are inverse operations? (Ask the students to help you with the following: What is the inverse of addition? (subtraction). What is the inverse of subtraction? (addition). What is the inverse of multiplication? (division). What is the inverse of division? (multiplication). It is often a good plan to follow the order of operations in reverse when solving equations that have more than one operation.

Some common mistakes to watch for:

•*students want to multiply/divide BEFORE adding/subtracting when solving two-step equations.*

•*students subtract a number from both sides whenever they see a subtraction sign in the problem-remind them that the opposite of subtraction is ADDITION*

Teacher-led examples

Solve each two-step equation using division. After solving, check each answer.

Example 1: Solve and check 2x + 3 = 15
Check answer: 2 (6) + 3 = ? (It equals 15, so we are correct!!)

Example 2: Solve and check $-4w + 7 = -17$
Check answer: $-4 (6) + 7 = ?$ (It equals -17)

Solve each two-step equation using multiplication. After solving, check each answer.

Example 3: Solve and check $5 + \underline{h} = 13$
Check answer: $5 + (16/2) = ?$ (It equals 13)

Example 4: Solve and check $m/5 - 8 = -14$
Check answer: $(-30/5) – 8 = ?$ (It equals -14)

As you go through the step of checking the solutions, students see the significance of the order of operations in solving equations.

PART II – ACTIVITY – 20 MINUTES

I have, Who has? Materials needed: index cards

Place each individual line on an index cards. When students receive their index card (Give out every card so that the activity will "work". This means that some students may have two cards OR students may have to work in pairs where each pair has a card.) The teacher will keep the START card. Before beginning the activity, have students work out the equation on the card under WHO HAS? This will allow them to have an answer ready when their card is called and help the activity go more smoothly.) If some-one breaks the "chain", have each person solve their equation under WHO HAS? again to make certain they have the correct answer. If they have solved their equations properly, then they should go in the order below. The equations with fractions (where multiplication is required to solve) have the fractions given in parentheses. Once everyone has their equation under WHO HAS? solved, begin the activity by reading the Start card.

I HAVE WHO HAS?

Start

5 $2x + 3 = 7$

2 $-6x - 1 = 5$

-1 (x/6) + 2 = 4

12 4m – 8 = -24

-4 (r/9) – 5 = 1

54 -3p – 8 = 19

-9 2x + 3 = 23

10 8 + (a/4) = 2

-24 (u/3) + 6 = 18

36 -11 – 3m = -20

3 5x + 6 = 41

7 (m/-7) – 14 = 2

-112 -7 + (r/3) = 3

30 -4w – 2 = 6

-2 (k/2) + 12 = 2

-20 9x – 4 = 41

PART III – APPLICATION/ASSESSMENT – 20 MINUTES

In the last 20 minutes, students should work individually on the following problems solving two-step equations. Use this time to monitor the progress of individual students.

Solve the following equations. Make sure to check each answer.

1. 2x + 3 = 5 (answer: 1)
2. 5x – 2 = -7 (answer: -1)
3. M/2 + 32 = 40 (answer: 16)
4. 13 + y/-7 = 12 (answer: 7)
5. 2x -5 = -5 (answer: 0)
6. -3c + 14 = 8 (answer: 2)
7. (g/4) - 11 = 1 (answer: 48)

If time permits, have students go to the board to share solutions and answers with the class.