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Title: The Relationship between Gender, Ethnicity, and Technology on the Impact of Mathematics Achievement in an After-School Program

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Abstract Body

Background / Context:

The gap among ethnicities and gender in mathematics achievement is a well-known problem. While the gap has been shrinking over the past three decades, it has not completely diminished (Jencks & Phillips, 1998; McGraw, Lubienski, & Strutchens, 2006). Generally speaking, the test scores in math of African American students have lagged behind those of white students. And the gender gap favors male students over female students. However, a more accurate description often mixes the effect of ethnicity and gender (Catsambis, 1994; Kao & Thompson, 2003; Riegle-Crumb, C., 2006; McGraw et al., 2006; Else-Quest, N. M., Mineo, C. C., & Higgins, A., 2013). A study of 8th grade students showed that the gender difference was the smallest among African Americans when compared to Latino and White students (Catsambis, 1994). McGraw and his colleagues (2006) also indicated that the male students' advantage in math mostly occurred in White students and does not exist among African American students. Else-Quest et al. (2013) reported that, for 10th grade students, the females and males earn similar grades in math and science independent of ethnic group (White, African American, Latino/Latina, and Asian American). The differences of gender favoring males occurred in the level of confidence and the expectations for success.

Many attempts to diminish the achievement gap among ethnicities and genders have been attempted, but have not fully succeeded. However, the development of new technology provides a new opportunity for decreasing these gaps. The ALEKS, Assessment and LEarning in Knowledge Spaces, tutoring system is one promising example of a technology that can target this problem.

ALEKS is a Web-based intelligent tutoring system (ITS) that instructs students on the mathematical topics that they are most ready to learn. The system design was motivated by research at New York University and the University of California, Irvine, by a team of software engineers, mathematicians, and cognitive scientists with support from a National Science Foundation grant. ALEKS has an artificial intelligence engine that assesses each student individually and continuously at a fine-grain rather than a course-grain level. It assesses students' current knowledge, instructs students on the topics they are most ready to learn, and evaluates student performance on problems related to those topics.

Hu and colleagues (2013) reported that intelligent tutoring system (ITS) can help reduce the gap between white and African American students. They (Hu et al, 2013) introduced ALEKS into undergraduate behavioral statistics classes. Some classes used the ALEKS system while the other classes used traditional lecture based classes. The results showed that the performance of African American students was slightly better than White students in the ALEKS condition, while Whites performed significantly better than African Americans in the teacher condition. A similar pattern of data have been found for 6th grade students in Mathematics in which large achievement gaps were observed in favor of White students over African-American students at pretest, but the achievement gap disappeared at posttest after using ALEKS (Cheney et al., 2011).

In order to better understand the role that technology can play in decreasing achievement gaps for gender and ethnicity, we examined the effect of interacting with ALEKS in the 6th grade students' math after-school program. The prior study (Hu et al, 2013) emphasized the importance of considering student performance prior to the course when studying ethnic gaps (e.g. ACT Math and Cumulative GPA). Therefore, we use the 5th grade score of an annual state test, the Tennessee Comprehensive Assessment Program (TCAP), to represent the students' math

performance before the intervention. Also, we used the 6th grade TCAP score as the after-intervention math performance.

Therefore, the purpose of this study was to clarify the effectiveness of intelligent tutoring system to reduce the achievement gap among ethnicities and genders in an after-school math program for 6th grade students. Students were self-selected into the program. Then they were randomly assigned into either the ALEKS condition or second teacher condition that receives traditional style instruction from human teachers. This is a multiyear study. So far overall results for year one has shown that there was not a significant difference between the ALEKS condition and the control taught by human teachers, but the mathematics scores for students in the program was significantly higher than students not in the program (Hu et al., 2012). Similarly for the second year, there was no different observed between conditions. However, students in the ALEKS condition required less assistance and supervision (Craig et al., 2013).

Purpose / Objective / Research Question / Focus of Study:

This study aims to test how the intelligent tutoring system, ALEKS, can be used to reduce the gap of student mathematics achievement among ethnicities and genders in an after-school setting for 6th grade students. ALEKS founded on the idea that students should learn material as they are ready for it. ALEKS adaptively selects the next skill for a student to work on. The system attempts to fill learning deficits and correct misconceptions adaptively and dynamically using Knowledge Space Theory (Hu et al., 2012). It tracks the knowledge states of learners in fine detail and adaptively responds with assignments that are sensitive to these knowledge states.

To do so, we implement a randomized experiment in which students are either assigned to use ALEKS or are assigned to be taught structured lesson plans from a teacher. As such, we aim to answer the research question: Does ALEKS reduce the math achievement gap between two ethnicities (White and African American) comparing to a teacher?

Setting:

The experiment is conducted as an after-school program at five secondary schools in a school district in west Tennessee. The district serves both a midsized city and the surrounding county serving a total 13,607 students in grades Pre-K–12 distributed among 28 schools. The school system serves a largely economically disadvantaged population (68.2%) and a majority minority student enrollment (56.3% African American, 3.4% Hispanic, 39.3% White, and 1% other).

Population / Participants / Subjects:

Previous study has shown that sufficient time in the program is needed before it becomes effective (Craig et al., 2011). So, this study focused on 102 students with excellent attendance (45 out of 50 days). This left the teacher condition with 22 males, 29 females; 11 white students and 40 African American students. The ALEKS condition had 28 males, 23 females; 11 white students and 40 African American students. This group comes from a total of 776 participants volunteered for our after-school program at the academic year 2010-2011 and 2011-2012.

Intervention / Program / Practice:

Students who self-selected to the after-school program were randomly assigned to one of two conditions (ALEKS & Teacher). Students in both conditions attended the program two days

a week for two hours each day. The program was conducted for 25 weeks with 40 days of instruction and 10 days of review assessments.

Each two-hour session was divided into five 20-minute segments with 10-minute periods for start-up and dismissal. The students received three 20-minute instruction sessions. The instruction sessions were separated by two 20-minute *down-time* sessions during which students received snacks (1st break) and played games (2nd break).

In the ALEKS condition, students interacted with the program during each of the 20-minute instructional sessions. The program gave the problems appropriate to their current knowledge space. Upon mastery of a topic, the student is given instruction for the next topic in that area. The student was able to select this topic from a list of problems selected based on their current knowledge space (See Figure 1).

In the teacher condition, each of the 20-minute sessions was highly structured. The material to be covered was selected prior to the start of the program from the State Performance Indicators (SPI) topic(s). In particular, the SPIs selected were those that students typically missed and best would align with the needs of the student population. Members of the research team designed very structured lesson plans for each day of instruction. For example, during the first instructional 20-minute session teachers gave a short lecture and a demonstration of how to work through problems. During the second 20-minute session, the class worked as a group and with the teacher to complete a set of problems going over the material discussed while during the third 20-minute session, students worked on their own.

For both the ALEKS and teacher conditions the outcome measure of performance was the Tennessee Comprehensive Assessment Program (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. We use the TCAP normal curve equivalent score, which is the adjusted scores that gives the student relative rank among all Tennessee students. The scores of the 5th grade TCAP were used to assess students' pre-program mathematics achievement whereas the scores of the 6th grade TCAP were used as the posttest.

Research Design:

This study used a randomized experiment with treatment and control group to gauge and compare the effect of ALEKS software to a human teacher in reducing achievement gap in mathematics. As stated above, students who volunteered for the study were then subsequently randomly assigned to the ALEKS condition or the teacher condition.

Data Collection and Analysis:

Data were collected through the district as well as through the program itself. 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) and 6th grade (after the program). The program collected information as to how often students attended. Each teacher in the teacher condition and each monitor in the ALEKS condition kept student role throughout the duration of the program.

We used student performance on the 6th grade TCAP as a dependent variable looking for differences between Condition, Gender, and Ethnicity while using 5th grade TCAP scores for mathematics as a covariate.

Findings / Results:

The study was done at five schools in the same school district. An ANOVA showed that the schools did not have significant impact on the pretest score (5th grade TCAP), $F(4, 98) = .219$, $p = .927$.

The 5th grade TCAP scores of the students in the teacher condition did not indicate any significance among genders and ethnicities. In the ALEKS condition, there was an marginally significant 2 (Ethnicity: African American; White) X 2 (Gender: Male; Female) interaction, $F(1, 48) = 3.582$, $p = .064$; $\eta^2 = .069$. Follow up analyses showed a difference between White male and African-American male, $F(1, 27) = 3.117$, $p = .089$; $\eta^2 = .103$. Means and standard deviations for 5th grade TCAP scores can be found in Table 1.

A 2 (Condition: Teacher; ALEKS) X 2 (Gender: Male; Female) X 2 (Ethnicity: African American; White) ANCOVA was conducted on student's 6th grade TCAP scores using student's 5th grade TCAP scores as the covariate. This analysis indicated a significant three-way interaction, $F(1, 93) = 5.354$, $p = .023$; $\eta^2 = .054$. Means and standard deviations for the 6th grade TCAP scores adjusted by 5th grade TCAP scores can be found in Table 1. Follow up analyses found that there were no significant differences among groups in the ALEKS condition while there was an marginally significant difference on a 2 (Gender: Male; Female) X 2 (Ethnicity: African American; White) ANCOVA for students in the teacher condition, $F(1, 46) = 3.094$, $p = .085$, $\eta^2 = .063$. The result indicated a tendency that white males underperformed in the teacher condition while they were the top performer in the ALEKS condition. However, the result needs replication since there may a sample bias for a limited number of white participants.

It should be noticed that, in the ALEKS condition, there was an achievement gap between white males and African American males at the 5th grade. After interacting with ALEKS for the complete program, the African-American males' achievement gap with other students has been narrowed. The marginally significant effect disappeared. ALEKS's ability to reduce African-American students' achievement gap has been found by Cheney et al.'s (2011). One reason could be the ability difference of the ALEKS and teachers in fulfilling of the individual needs of the male students. ALEKS adaptively responds learners with assignments that a sensitive to their ready-to-learn knowledge states. However, the individual needs of the lowest and highest performers may be ignored by the teacher while the majority of the students in the classroom are the average performers.

Conclusions:

It appears that the ITS (ALEKS) helps reducing the achievement gap between ethnicities. While more research is needed, it would appear that the ALEKS condition was able to offer equivalent help to students with different levels of performances, while the teachers' help tends to average performers.

Appendices

Not included in page count.

Appendix A. References

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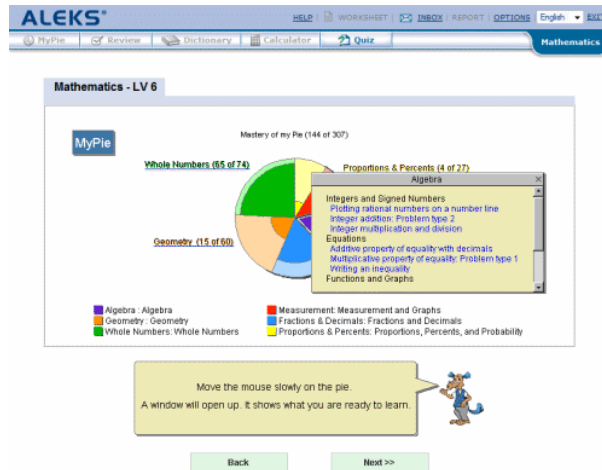
Appendix B. Tables and Figures

Figure 1. Screenshot of the ALEKS problem selection interface

Table 1.
The means and standard deviation on 5th grade and adjusted 6th grade TCAP scores for all cells for Gender, Ethnicity, and condition. This table also includes the number of students that attended more than 45 days.

		Teacher condition				
		5th Grade TCAP		6th Grade TCAP		n
		M	SD	M	SD	
White	Male	47.25	24.905	38.89	24.91	4
	Female	55.43	21.31	51.77	21.31	7
African-American	Male	48.44	14.14	48.50	14.14	18
	Female	43.27	17.90	44.55	17.897	22
		ALEKS condition				
		5th Grade TCAP		6th Grade TCAP		n
		M	SD	M	SD	
White	Male	59.80	15.09	54.93	15.09	5
	Female	41.83	19.51	43.71	19.51	6
African-American	Male	39.91	14.10	43.94	14.10	23
	Female	47.12	16.77	45.83	16.766	17