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EDU2017-2423

Is Computer-Assisted Instruction (CAI) Reliable to Promote Students’ Mathematical Reasoning?

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This paper should be cited as follows:

Kitchen, R., S. (2018). **"Is Computer-Assisted Instruction (CAI) Reliable to Promote Students' Mathematical Reasoning?",** Athens: ATINER'S Conference Paper Series, No: **EDU2017-2423.**

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URL Conference Papers Series: www.atiner.gr/papers.htm

ISSN: 2241-2891
04/04/2018

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Abstract

In this paper, we examine how five high school mathematics teacher leaders who work in a highly diverse, urban school district view computer assisted instruction (CAI) with regards to its role in promoting equity in mathematics in their district. Our goal is to understand how CAI promotes or hinders the mathematics education of students who have historically been denied access to a high quality mathematics education in the U.S.; low-income students, and culturally and/or linguistically diverse students. We address the following research question: What views do five high school mathematics teacher leaders have with regards to the role that CAI is playing to promote or hinder equity in mathematics education in their district? Our findings indicate that CAI is being used in the participating teachers' school district primarily as a means for students to recover mathematics credits needed to graduate. Participants worried that students who use CAI for credit recovery are not learning mathematics for understanding. In addition, participants were concerned that CAI use does not promote mathematical understanding. The participants agreed that administrators in their school district were aware of potential shortcomings of CAI and were looking to make some changes.

Keywords: Computer Assisted Instruction, Equity in Mathematics Education, Mathematical Discourse, Mathematical Reasoning

In this paper, I examine how five high school mathematics teacher leaders who work in a highly diverse, urban school district view computer assisted instruction (CAI) with regards to its role in promoting equity in mathematics in their district. My goal is to understand how CAI promotes or hinders the mathematics education of students who have historically been denied access to a high quality mathematics education in the U.S.; low-income students, and culturally and/or linguistically diverse students (underserved students) (See, for example, Kitchen, DePree, Celedón-Pattichis, & Brinkerhoff, 2007; Martin, & Leonard, 2013; Téllez, Moschkovich, & Civil, 2011). I address the following research question: What views do five high school mathematics teacher leaders have with regards to the role that CAI is playing to promote or hinder equity in mathematics education in their district?

Since standards-based mathematics instruction is often not a priority at schools attended primarily by underserved students (Kitchen, 2003; Martin, 2013), it is important to study the role CAI is playing vis-à-vis low-level, skills-based mathematics instruction that has been documented for years to pervade in schools populated by underserved students in the U.S. (Davis & Martin, 2008; Secada, 1995). Given the growth of educational technology companies and the associated expansion of CAI in schools (DeSantis, 2012), it is important to ask how CAI may support or hinder standards-based reforms in mathematics (e.g., development of students' reasoning through problem solving and discourse), particularly in schools that serve low-income students and students of color? Throughout, I use computer-assisted instruction (CAI) as synonymous with computer-based interventions and computer-based training. I adopt the commonly held perspective that CAI is an instructional approach in which a computer, rather than an instructor, provides self-paced student instruction, tests and learning feedback <http://edutechwiki.unige.ch/en/Computer-based_training>. Dynamic geometry software (see, for example, Jones, 2000) and video game interventions (see, for example, Barab, Gresalfi, & Ingram-Goble, 2010) do not meet this definition of CAI. To be clear, it is not my intent to characterize CAI programs as uniform since large differences exist. For instance, programs vary in terms of interactivity, use of graphics, and versatility (SEDL, 2013). Some are software programs, while others are web-based. In addition, we recognize that there are at least three different applications of CAI (supplemental, core, and computer-managed learning systems) in the classroom (Slavin, Lake & Groff; 2009). The concerns expressed here are intended to apply generally to any CAI intervention program designed for use in mathematics classrooms in U.S. schools, and some of these concerns may apply for some CAI programs and not for others.

In recent years, there has been an influx of federal dollars for educational interventions for Title I schools as part of the No Child Left Behind legislation (NCLB), ("No Child Left Behind," 2012). In 2012, $14.5 billion of NCLB funding was devoted to Title I grants to low-performing school districts throughout the U.S. (New American Foundation, 2012). Educational technology companies are benefitting greatly from this federal spending. Nationwide, investments in educational technology companies have tripled in the last decade from $146 million to $429 million in 2011 (DeSantis, 2012).

More than 21 million students attend a Title I school in the U.S. (U.S. Department of Education, 2011), or approximately 44% of all students in grades K-12 (Hussar & Bailey, 2013). Because of the large investment of NCLB dollars into education technology such as CAI in Title I schools, we believe it is important to understand the impact that CAI is having on mathematics instruction in these schools. Importantly, U.S. schools receiving Title I funds that pay for CAI enroll large populations of underserved students (Gray, Thomas, & Lewis, 2010). A concern for us is that Title I schools disproportionally use educational technology such as CAI to "learn or practice basic skills" (Gray, et al., 2010, p. 3); 83% of students attending a Title I school experience technology primarily for skill development compared to 61% of their counterparts at non-Title I schools.

Mathematical Reasoning and Discourse

To implement standards-based reforms in mathematics, teachers need to possess a solid understanding of mathematics and have the pedagogical skills needed to support their students to learn mathematics with understanding (Franke & Kazemi, 2001; Hill, Rowan, & Ball, 2005). Reasoning is central to standards-based reforms in mathematics because to engage in rigorous problem solving as advocated in the CCSS, students need to develop strong mathematical reasoning skills. For us, mathematical reasoning is synonymous with Blanton and Kaput's (2005) definition of algebraic reasoning as "a process in which students generalize mathematical ideas from a set of particular instances, establish those generalizations through the discourse of argumentation, and express them in increasingly formal and age-appropriate ways" (p. 413).

A focal point of the CCSS is the "Standards for Mathematical Practice" that advocate for developing students' abilities to reason mathematically across the K-12 curriculum ("Standards for Mathematical Practice," 2012b). Among the eight standards listed in this domain, mathematical reasoning is prominent in three of them; Math Practice (MP) 2 "Reason abstractly and quantitatively," MP 3 **"**Construct viable arguments and critique the reasoning of others," and MP 8 **"**Look for and express regularity in repeated reasoning." Reasoning and proof were also significant process standards in mathematics education reform policy documents that foreshadowed the Standards for Mathematical Practice recommended in the CCSS (see, for example, NCTM, 1989; NCTM, 2000; NSF, 1996).

Another prominent feature of the CCSS is the value placed upon mathematical conversations or discourse. Historically grounded in the Socratic tradition, in mathematical discourse, the teacher seeks to foster and continually engage in dialogue with her students (Cazden, 2001; Herbel-Eisenmann & Cirillo, 2009). Research has demonstrated that when students have opportunities to engage in mathematical discourse to explain their ideas to peers and to listen to and make sense of the ideas of others, their learning is enhanced (See, for example, Webb, 1991; Herbel-Eisenmann & Cirillo, 2009). As students engage in mathematical discourse through participation in learning communities, they build on their prior experiences and knowledge to achieve more advanced understandings of challenging mathematical concepts (Lave & Wenger, 1991; Stein, Silver, & Smith, 1998; Franke & Kazemi, 2001).

Mathematics Education for Low-Income Students and Students of Color

In 2012, the poverty rate was 15%, or 46.5 million people lived in poverty in the U.S. (DeNavas-Walt, Proctor, & Smith, 2013). The poverty rate for ethnic and racial minorities in the U.S. greatly exceeds the national average; in 2010, 27.4% of blacks and 26.6% of Hispanics were poor, compared to 9.9% of non-Hispanic whites and 12.1% of Asians (National Poverty Center, 2010). Also in 2010, the poverty rate for children under the age of 18 was 22%, but for black children it was 38.2% and Hispanic children it was 35%. Massey (2009) contended that advantages and disadvantages procured from an individual's socioeconomic status (SES) are both reinforced and compounded by geographic concentration, what Tate (2008) refers to as the "geography of opportunity" (p. 397). For instance, students from low-income communities attend schools in which pupil expenditures compare unfavorably to pupil expenditures in schools located in wealthy communities and achieve at lower levels than their wealthy counterparts (Payne & Biddle, 1999). Hogrebe and Tate (2012) found that algebra performance is also influenced by where students live; the SES of local communities is significantly related to students' performance in algebra. Brynes and Miller (2007) argued that SES has direct effects on mathematics achievement and indirect effects on both the opportunities students have to enroll in advanced mathematics classes in high school and on their propensity to take advantage of learning opportunities in mathematics.

In addition to poverty and SES, student access to a challenging standards-based mathematics education is influenced by race, ethnicity, and English language proficiency (DiME, 2007; Gutiérrez, 2008; Martin, 2013). For instance, schools that enroll large numbers of African American students often have disproportionally high numbers of remedial classes in mathematics in which instruction is focused on rote-learning and strategies that are intended to help students be successful on standardized tests (Davis & Martin, 2008; Lattimore, 2005). In response to NCLB (2001) and the demands to increase test scores, Davis and Martin (2008) argue that the preponderance of skills based instruction "[negatively] shape the lives of poor African American students in more significant ways than middle-class or affluent students" (p. 18). In schools that serve large numbers of immigrant Latino/a students who speak with an accent, use English words incorrectly or speak in Spanish as a means to express themselves, educators, peers and community members may assume they lack the capacity to perform well in mathematics (Gutiérrez, 2008; Moll & Ruiz, 2002; Moschkovich, 2007). Ability grouping or tracking is another widespread practice in the U.S. that has disproportionally hurt students of color (Oakes, 2005; Secada, 1992). Tracking continues to "divide students by perceptions of 'ability' and communicate to students the idea that only some people—particularly white, middle class people—can be good at mathematics" (Boaler, 2011, p. 7).

Given the high percentage of students of color living in poverty in the U.S. and the extensive research base that demonstrates that low academic expectations and lower pupil expenditures have historically been the norm at schools that serve low-income communities and students of color (See, for example, DiME, 2007; Ferguson, 1998; Flores, 2008; Knapp & Woolverton, 1995; Payne & Biddle, 1999), it is not difficult to surmise that millions of students are being denied access to instruction in which mathematical reasoning and discourse are used to solve complex tasks (Davis & Martin, 2008; Kitchen, Burr, & Castellón, 2010; Téllez, Moschkovich, & Civil, 2011). Since standards-based mathematics instruction may not be a priority at schools attended primarily by underserved students (Kitchen, 2003; Martin, 2013), and, as previously noted, 83% of students attending a Title I school experience technology primarily for skill development (Gray, et al., 2010), we worry about the role that CAI may play to exacerbate the negative consequences of NCLB for underserved students.

Some Background on Educational Technology and Research on CAI

The educational technology market is a big business. In a 2011 survey by the Software & Information Industry Association (SIIA), the overall market value for grades preK-12 non-hardware educational technology was $7.5 billion (Software & Information Industry Association, 2011). Since 2011, federal funding for educational technology in K-12 schools has been integrated into other funding streams in order to make technology expenditures more efficient for schools (Pascopella, 2012). This makes it difficult to track how much of the 2013 Education Department budget of $69.8 billion (U.S. Government Printing Office, 2013) is actually spent on educational technology (Pascopella, 2012). However, it is safe to say that educational technology companies are largely dependent upon school districts, the main consumers of CAI (New American Foundation, 2012).

Research has demonstrated that CAI has both strengths and weaknesses, but overall its effect on student achievement is inconclusive. Among the strengths, students are provided with immediate feedback on their performance, instruction is individualized, and the program maintains evaluative information concerning students' progress (Kulik & Kulik, 1991; Lockard, Abrams, & Many, 1997). Hu, et al. (2011) found that students who participated in an afterschool program in which they received tutoring via a CAI program performed significantly better on a standardized test than non-participating peer students, and that these students' mean scores were equivalent to or higher (not statistically significant) than scores of students receiving afterschool tutoring from teachers. Additionally, Slavin and Lake (2008) found in their review of CAI programs designed for use with elementary school students that "CAI effects in math, although modest in median effect size, are important in light of the fact that in most studies, CAI was used for only about 30 minutes three times a week or less" (p. 481). Summarizing their findings, Slavin and Lake (2008) wrote "A number of studies showed substantial positive effects of using CAI strategies, especially for computations, across many types of programs" (p. 481).

In terms of weaknesses, studies have also shown that use of CAI does not impact student achievement in mathematics. For example, Cavanagh (2008) found a CAI program to have "no discernible effect" (p. 4) on student achievement. As part of NCLB, Congress requested a $15 million study by the U.S. Department of Education to examine the effectiveness of 10 different mathematics and reading educational software technology products (Gabriel & Richtel, 2011). The report was released in 2007 and compiled from the 2004-2005 and 2005-2006 school years. The findings indicated that the "evaluation found no significant difference in student achievement between the classrooms that used the technology products and the classrooms that did not" (Institute of Education Sciences, 2009, p. xvi). This report focused on technology products in mathematics and reading, and none of the mathematics technology effects were statistically significant. Moreover, Slavin, Lake and Groff (2009) determined in their extensive review of CAI programs designed for use with middle school and high school students that "effect sizes were very small" (p. 839).

Given the inconclusive, and at times, contradictory research concerning the effects of CAI on mathematics learning and achievement, we wonder why schools are investing such significant financial resources and valuable classroom time towards these educational technology products. A 2010 survey asked school leaders and district officials how they chose curricula and 58% responded that they had never heard of or consulted What Works Clearinghouse, an initiative of the U.S. Department of Education that reviews education research and publishes findings relevant to school leaders ("Department of Education," 2010). Many experts believe it is more a matter of slick public relations pitches rather than the effectiveness of the actual products that persuade sales, and that decisions to purchase are based on politics, personal preferences, and marketing (Gabriel & Richtel, 2011).

Methodology and Data Sources

The data collected to answer the two research questions were audiotaped interviews conducted with the individual participating teacher leaders. One classroom observation was also made of Mr. A, the participating teacher leader who taught mathematics using CAI. All five participating teacher leaders provided consent to participate in the study. At the time the study was undertaken, all five research participants were leaders in mathematics in their district, a highly diverse urban district that enrolled nearly 40,000 students. In 2014-15, approximately 55% of the students enrolled in their district were Hispanic, 19% were Black, 17% were White, and 5% were Asian. In the spring semester of 2016, we met with the five research participants to conduct the individual interviews. This was also when we conducted the classroom observation of one of Mr. A's classes. Interviews with individual teacher leaders were 40-50 minutes in length.

For the purposes of this study, the data analyzed included all interviews conducted with participating teacher leaders and the classroom observation made. The interview transcripts were analyzed using interpretive methods (Erickson, 1986; Maxwell, 2005). Each interview was read as a whole, followed by a period of open coding to allow for the emergence of themes, and themes were then compared across interviews conducted. After a set of themes were obtained from the dataset, we searched for commonalities and differences across interviews conducted (Miles, Huberman, & Saldaña, 2013). We also sought both confirming and disconfirming evidence by searching for supportive and non-supportive evidence (Erickson, 1986; Miles, Huberman, & Saldaña, 2013).

The five teacher who participated in this study were Mr. A, Ms. G, Ms. K, Mr. O, and Ms. V. At the time the study was undertaken, Mr. A, Mr. O, and Ms. V were all practicing high school mathematics teachers. Ms. G was a district mathematics coordinator and Ms. K was a mathematics coach at a district high school. Ms. V was the most junior teacher among the practicing teachers. All five participants are white.

Our findings indicate that CAI is being used in the participating teachers' school district primarily as a means for students to recover mathematics credits needed to graduate. Participants worry that students who use CAI for credit recovery are not learning mathematics for understanding.

CAI is Primarily Used for Credit Recovery and Remediation

Teachers described how BOB, the primary CAI program used in the district, was primarily being used as a means for seniors who needed additional credits in mathematics to graduate. In the participating teachers' school district, four mathematics credits were required for graduation (four years of mathematics classes). Ms. K told us:

BOB is our credit recovery class. It is a joke to be perfectly honest. Kids supposedly watch videos and do practice problems, more of the drill and kill kind of stuff. Here's how you do the Pythagorean Theorem, now go practice it. So there is really no contextual base with those things, it is really just the remediation and the low skill sort of thing… The hard part too is that the kids really don't have anybody to communicate with. BOB is run by a Para [Paraprofessional] with no math background. So the Para can't even help them relate ideas, can't help them work on the problems, none of that. And so the only way a kid can get any support in this BOB program is if they go out and seek their math teacher and say, 'I don't understand this' or whatever. But, the truth is that doesn't happen at all."

In addition to being used largely for credit recovery purposes in mathematics and other subject areas, Ms. K explained how students are essentially on their own when they use BOB. Ms. G explained that BOB was also being used as a tool to support remediation for those students who needed it:

In general, I think for the most part, computers and tech are seen as an aid for intervention. So, when I notice that the kids don't have such and such skill, then we'll have them practice that on the computer. Or, when they fail this class and need credit recovery, we'll have them do that on the computer. So, I think it's more often thought of as an intervention rather than tier I instruction kind of a tool.

Mr. O and Ms. V also shared in their interviews how BOB was also being used at their schools primarily for credit recovery for those students who were short the required four mathematics credits needed to graduate. Mr. A had taken on the task on field testing BUB, an alternative CIA program to BOB. Several sections had been established at his school for struggling mathematics students. These classes were intentionally small so that Mr. A could work closely with students and develop positive relationships with them (something that was valued at his school and in the school district). He explained some of what he liked about BUB:

Sometimes, we treat kids like they have the same background… A lot of people provide the same kind of instruction, like it's all at the board. That's the thing that I like about BUB is that it's not all the same type of instruction. There's obviously the stuff at the front of the board, there's the group work and stuff, but there's also opportunities for kids to work and use manipulatives and go around the room and do station activities and just hit kids in different ways so that they can understand math in different ways…. It hits more kids because it allows them to learn it in their own way.

In our observation of Mr. A's class, instruction would have been considered relatively traditional in that Mr. A provided many of the mathematical explanations, though we did notice that students were highly engaged in the lesson. BUB was used much like a textbook, which prompted us to ask him how BUB differed from a textbook? Mr. A replied, "I don't know that it's super different from a textbook. A textbook always has the opening part of the textbook, you'll have the main ideas, the vocab and examples. BUB goes through all that stuff… It does the same stuff. The biggest difference is that you don't have to lug around a big heavy book and the cost is significantly less for a class." You can also access BUB on-line.

Participants worry that CAI use does not promote mathematical understanding

Teacher leaders discussed how BOB did not necessarily promote mathematical understanding. Mr. O told us that from a mathematical standpoint, it (the content) is in no way related to what they may have missed out on [mathematics credit hours that are unfulfilled]. So, in Freshman Linear I, they do a lot of linear proportions. BOB doesn't classify it as linear proportions, they just classify it as a credit of Integrated I. I don't think they even line up with each other.

He also noted that "In BOB, in my opinion, students aren't actually learning." He added, "I've seen students work through 6 lessons in 12 minutes… They didn't pay attention to any of the lessons. Our students in BOB haven't had success in any classrooms and are not being put into a position to even have success with the on-line program." Ms. V shared a similar example of a student who made up 12 credits of 22 required credits for graduation in just 3 days by working day and night to recover credits. She shared that "Students know that BOB is the easy way out with earning credit for a class. It promotes a really shallow approach to learning and removes the life behind the curriculum. It also takes away talking about math. BOB has become a quick and easy band-aid."

Ms. G talked about what CAI should ideally accomplish:

What I look for with computers assisting with learning mathematics for understanding is that I don't think there's really much out there that's really leveraging what's possible. I mentioned the Desmos teacher activities. I think those are ones that I think really have some potential.

Ms. K compared and contrasted the two CAI programs that were in use at her high school: "I think BOB is much more traditionally drill and kill, whereas BUB is much more embedded in context and real-world applications. They are both meant to be individual, but BOB is get through it and get done, whereas BUB is get through it with an understanding and be able to apply it." She continued by explaining her belief that a Paraprofessional could probably learn how to teach mathematics for understanding with BUB because the program includes context that students can relate to, details "what we are going to talk about, and summarizes what the kids need to know by the time we are done. That is the piece that does not happen in BOB…"

Discussion

In this study, we learned that CAI is being used primarily at high schools in a highly diverse school district for credit recovery and remediation. However, there were attempts to use CAI in a proactive to support the mathematical learning of students who may have already failed a mathematics class. While these attempts resulted in some successes (e.g., students in these classes had higher completion rates than students in other mathematics classes), it was not clear to us if CAI was the reason for this or that these successes could be attributed to smaller class sizes and a personable teacher who made establishing positive relationships with his students a priority. Teachers expressed concern that while CAI helped students to recover needed credit hours in mathematics to meet graduation requirements, the use of CAI generally did not promote mathematical understanding. This was particularly problematic for Mr. O who was concerned that BOB, the CAI program used in the district for credit recovery was inequitable because though it helped seniors to be able to graduate on time, it was not preparing students for success after finishing high school. "That comes back to math equity of here's the curriculum that you're going to get, rather than this is the curriculum that you need."

Though the teacher leaders agreed that the widespread use of BOB was problematic because it was not aligned to the mathematics curriculum in use and because it did not support the learning of mathematics with understanding, they also agreed that the district was aware of BOB's shortcomings and were looking to make some changes. What those changes might be was unclear. However, in a district where administrators were under tremendous duress to graduate as many students as possible, particularly underserved students (Kitchen, et al., 2016), BOB served the vital function of increasing graduation rates. BOB was used heavily throughout the district for credit recovery in mathematics, and in other subject areas as well. Ms. K told us that, "Desperate times require desperate measures! Kids can take a semester long math class in 4-6 weeks and get their credit that they need. Its quick and we don't have to pay a teacher's salary." Ms. V illuminated that BOB was in such heavy demand at her school that the primary computer lab at her school was dedicated every day, all day long to BOB. She also told us about how night school had recently been established at her school for students who needed to work and how all they did in night school was study units in BOB.

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