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The SunBay Digital Mathematics Project: An Infrastructural and Capacity-Based Approach to Improving Mathematics Teaching and Learning at Scale

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Abstract: This paper discusses the first year of the SunBay Digital Mathematics Project (SunBay Math) and the project's implications for educational reform. It reviews the research literature on the SimCalc replacement unit *Managing the Soccer Team* and describes the unit's implementation in a large, urban district. Findings from professional development experiences, teacher observations, and student gain scores are shared. Similar to the results published in Roschelle, Shechtman, et al. (2010), there was a large and significant increase in mathematics understanding for SunBay Math students who learned in classrooms implementing *Managing the Soccer Team* in contrast to students in Texas control classrooms.

Introduction

This paper describes the first phase of a multi-year effort to raise the quality of middle grades mathematics instruction at scale in a large and diverse urban district. Its purpose is to describe the partnership of a college of education (the College), a nonprofit research organization (the Nonprofit), and a large, urban school district (the District) to provide intensive professional development (PD) to middle school mathematics teachers using computer-based, dynamic curricular materials designed to increase students' abilities to engage in complex mathematics, particularly algebra, and to change the way District teachers teach.

The SunBay Digital Mathematics Project (SunBay Math) is organized around an infrastructural and capacity-based perspective on instructional improvement. We define *infrastructure* as the tools teachers use to deliver instruction (Kaput & Hegedus, 2007; Roschelle, Tatar, & Kaput, 2008). These tools include the textbooks and paper workbooks that have become a familiar part of mathematics education in many classrooms around the world, as well as innovative technologies such as dynamic simulations and networks of handheld devices. We understand *capacity* as the human and organizational resources that enable school professionals to use these tools skillfully (Cohen & Ball, 1999; Massell, 2000). Capacity, in our perspective, exists in the systems of instructional leadership, networks of professionals, and other organizational resources supporting high quality teaching and learning (Fishman, 2006; Resnick, 2010; Stein & Coburn, 2008). SunBay Math's long term goal is to change what and how teachers teach by using dynamic technology and well-researched replacement units to augment the District's middle grades' mathematics curriculum and build the capacity to enable every teacher to use this infrastructure well.

The Research Supporting SunBay Math's Infrastructure

SunBay Math's major reform strategy is to replace critical parts of the local curriculum with replacement instructional units that address core mathematics content (see Tatar et al., 2008; Vahey, Roy, & Fueyo, in press). These units employ computer-supported dynamic representations of real world phenomena (Kaput, 1994; Kaput & Hegedus, 2007), such as races between people, designed to support students' efforts to learn algebra and other complex mathematics. The representations are executable (Hegedus, Moreno, & Dalton, 2007) and, consistent with recommendations from Hiebert and Grouws (2007), support students' efforts to understand the meaning of the mathematics they study. The replacement learning unit discussed in this paper, *Managing the Soccer Team* (MST) (Knudsen, de Frondeville, & Rafanan, 2003), organizes dynamic representations from *SimCalc Mathworlds*[®] into lesson segments designed to foster understanding of ratio and proportionality. Algebraic symbols are introduced after students engage with graphs and other representations of motion phenomena in order to help students connect these big ideas with formal, mathematical notation (Vahey, Knudsen, Rafanan, & Lara-Meloy, in press).

Field studies show MST is both effective and robust (Roschelle, Shechtman, et al., 2010; Tatar, et al., 2008). By *effective*, we mean capable of producing measurable gains in student learning and other important educational outcomes. By *robust* we mean the unit shows "benefits for student learning when deployed consistently to a wide variety of students, teachers, and settings." (Roschelle, Tatar, Shechtman, & Knudsen, 2008, p. 151). The seventh grade experiment described by Roschelle, Shechtman, et al. (2010) recruited a randomly selected group of 140 teachers in 73 schools in Texas. Participants were divided, after attrition, into a Treatment group of 48 teachers, who used MST, and a Control group of 47 teachers, who taught similar content using their district's curriculum in a delayed-treatment design (Slavin, 2002). MST and Control teachers

received a two-day workshop focused on rate, proportionality, and other demanding mathematic topics. MST teachers were then given three extra days of PD on how to use the replacement unit and a fall workshop devoted to implementation planning.

Gain scores taken from the pre- and post-tests showed an effect size of .63 favoring the Treatment group (those classrooms that used MST). There were no significant differences between the gains of girls, Hispanic students, and free-lunch students compared to the gains of other students; all achieved high gains (Vahey, Lara-Meloy, & Knudsen, 2009). Low achievers, however, did show lower gains compared to other students when, as Roschelle, Pierson, et al. (2010) show, these at-risk students were placed in classrooms where the teacher produced low average gains. Importantly, there was no difference in gains generated by classrooms that started out with low average pre-test scores compared to classrooms that began with high pre-test scores. Thus, given sufficient teacher quality, MST was effective in classrooms with many low-achieving students.

In the next section we detail the first phase of SunBay Math's efforts to implement MST and improve the District's mathematics instruction at scale. SunBay Math's theory of improvement begins by creating a new infrastructure for mathematics instruction in local classrooms and the College. We then build capacity outwards by improving teachers' knowledge of mathematics instruction and implementing dynamic replacements units in breadth and depth (see SRI International & University of South Florida St. Petersburg, 2010).

Method

The investigation presented in this paper was conducted according to the principles of design-based research (DBR) (e. g. Cobb, Confrey, diSessa, Lehrer, & Schauble, 2003; Penuel, Fishman, Cheng, & Sabelli, 2011). In the DBR approach, emphasis is placed on examining a particular change program using both quantitative and qualitative methods in accords with a conceptual frame. Data are then *mixed* (Creswell, 2003) to deepen team members' understanding of the project's larger research questions and to guide participants' choices as the project unfolds. The goal is to construct a shared, empirically-based perspective—albeit one with varying levels of agreement—about the phenomena under investigation, the most beneficial ways to implement and improve the design, and the implications of findings for reform and theory-building. Sources of data collected during the first year of SunBay Math, instruments used, and findings team-members generated are discussed in SRI International and University of South Florida St. Petersburg (2010).

Building Capacity by Improving Teaching and Learning: Findings from SunBay Math's First Year

“The book does it that way, SimCalc does it this way. This way is better.” –Teacher discussing SimCalc software at August 2009, SunBay Math PD .

In June 2009, the SunBay Math partners began working to create a comprehensive plan to implement digital mathematics replacement units in local schools, refine the teams' understanding of specific needs within the District, and build implementation capacity at the College. The first unit the partners chose for implementation was MST. Following a suggestion in Fishman et al. (2009), a team of Florida experts was convened to ensure that the unit was aligned with Florida's state standards. The experts recommended mostly cosmetic changes and thus the version of MST used in SunBay Math is comparable to the unit Roschelle, Shechtman, et al. (2010) evaluated in Texas.

District Demographics and Teacher Recruitment

The District is located in a diverse urban area and is one of the largest in the State of Florida. It serves more than 100,000 students, of which more than 21,000 are in grades 6-8. Approximately 54% of the District's students live in poverty and about 40% are members of minority groups primarily Black (19%), and Hispanic (9%). The District manages 21 middle schools and employs approximately 250 middle school mathematics teachers. On June 2, 2009, the District's secondary mathematics supervisor sent emails to principals at 10 District middle schools asking leaders to select two 7th grade teachers from each school to participate in SunBay Math. Three of the original schools ultimately declined and were replaced with larger and lower SES schools. Fifteen 7th grade teachers at 7 District schools ultimately participated in SunBay Math's initial, summer PD session. All teachers received District PD credits and compensation for their time. Of the 15 trained teachers, 13 implemented the unit. The participating teachers varied in age from 26 to 61 years and ranged in experience from two to 24 years teaching. All were certified to teach mathematics, although most had previous careers outside of education and had received certification through alternative routes. Some were mathematics leaders within their schools, 3 were department heads, others said their principals “volunteered them” for the program.

August 2009: 3 Day Professional Development for MST

“We have a hard time teaching children why is the slope like this, or why is the slope like that. Now, I can say what ‘that’ means.” –Teacher at August 2009, SunBay Math PD.

Professional developers from the Non-Profit joined faculty from the College to help deliver a 3-day PD organized similar to the Texas PD experience described in Roschelle, Shechtman, et al. (2010). Teachers were asked to experience the unit as learners, and they worked with the professional developers to solve the mathematical problems posed by the unit. As discussed in Roy, Vanover, Fueyo, and Vahey (in press), SunBay's initial PD trainings were organized around 3 norms. These were:

- Do the math.
- Make bold conjectures.
- Think about your classrooms.

Teachers completed a workshop evaluation form and rated the PD on a Likert scale of 1 to 5 on characteristics such as pacing, organization of materials, and the extent the PD prepared them to teach the digital mathematics units. Teachers reported high levels of satisfaction; the average rating was 4.6 out of 5. During an opportunity for the teachers to discuss the workshop at the end of the third day, teachers praised the hands-on nature of the trainings and power of the dynamic unit. One teacher said, "I've been to a lot of trainings where I couldn't see it. [SunBay Math] helped me do it. I could see what I was doing and could imagine what I might do in my classroom." Another said, "What's great about this, is I don't have to develop all the parts of the lessons myself. SimCalc is already built. I can concentrate on teaching the lesson rather than doing the lesson."

Fall 2009: Monthly Evening Professional Development

To support implementation, teachers were provided with a 3-hour PD session once a month from September through December. Notes show that a majority of time during these trainings was spent working on key lessons, discussing the mathematical content embedded in the software and workbook, and brainstorming how best to use tools embedded in the units to support student achievement. Each session began with a "warm-up" mathematics question designed to get teachers thinking deeply about rate and proportionality.

Teachers provided an average rating over all workshops of 4.4 out of 5. In phone interviews conducted in December and January, teachers appreciated the professional community that grew out of these sessions. One teacher said, "I liked seeing where the unit was coming from. Going deeper with questioning strategies." Another said, "I liked the fact that they were...opening us up to ideas and strategies that I had forgotten or never learned. I didn't learn stuff just about SimCalc, but something about being a better teacher."

Implementation of MST: October-December 2009

SunBay Math team members from the College provided technical assistance for the 13 teachers to implement MST in their classrooms in the Fall of 2009. One key form of support was surveying the 7 schools' technology capabilities, meeting with technology and media staff, and working with the teachers to ensure that computers and SimCalc *MathWorlds*[®] software was available for the unit. College personnel logged more than 150 hours of time calling principals and technology coordinators ensuring teachers had access to computer labs or laptop carts, installing software, and troubleshooting technology dilemmas.

Twelve of the 13 teachers were observed during one of MST's major lessons, *On the Road*. The lesson's implementation might be described as variation within a theme. All teachers used the workbook to guide instruction. For example, while some engaged in pre-lesson reviews and examples, all had students read *On the Road*'s framing scenario, and then move through the workbook problems in order. There was wide variation, however, within this orchestration. Teachers varied in the pace of activities. Some, particularly those who had been identified by the team as less skillful technology users, moved quite slowly through the material—in these classrooms, just passing out computers and getting software loaded could take 10 minutes.

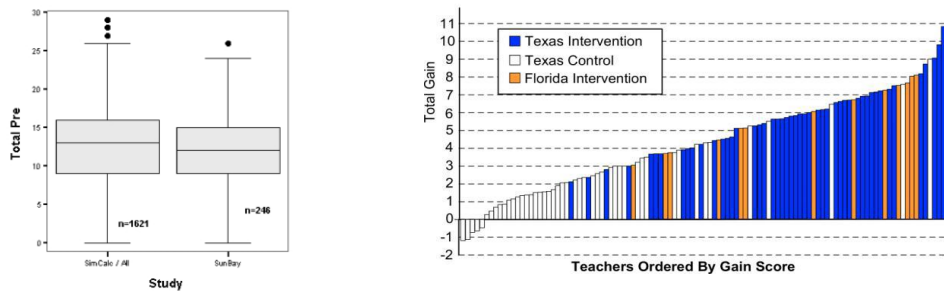
The team also observed a wide variety of classroom structures, both in terms of physical layout and the types of activities students engaged in when using computers. Some teachers tended to group students in pairs or small groups focused on a particular computer; others focused predominantly on whole-class activities and projected MST materials to the class using a LCD projector. While it may intuitively make sense that particular computer uses lead naturally to particular types of instruction, our observations show that this is not necessarily the case. Some teachers led inquiry-based whole class conversations using a single laptop and a LCD projector. Conversely, other teachers passed out enough laptops to enable students to work in pairs around a single computer, but used that infrastructure to lead the class in a directed way with little mathematical conversation. This variability replicates the Nonprofit's experience in Texas, where teachers adapted the use of the software to the mode they had available or with which they were most comfortable.

Results: Student Learning from MST and Comparisons to Texas

We compared the learning gains of the District students who used the MST unit ($n = 246$) with the learning gains of those students in the Texas study ($n = 825$) who used a slightly different version of the unit using the assessment instrument from Roschelle, Shechtman, et al. (2010). Figure 1 shows there was no statistically significant difference between the average pretest score of the SunBay students and the students in the Texas study (both Treatment and Control). Figure 2 shows the spread of mean gain scores for three

populations of students: Texas Control students (who did not use MST); Texas SimCalc students; and SunBay SimCalc students. Gain scores were calculated by subtracting students' pretest score from their posttest scores. The SunBay gain scores were almost identical to the Texas SimCalc gain scores, and both are significantly greater than the Texas Control gain scores. There was a large and significant main effect size for SunBay students in contrast to Texas Controls. Figure 2 shows teachers who did not use the Digital Mathematics materials had limited learning gains (indicated by the large number of Control teachers grouped to the left of the graph). This graph also shows that all teachers who used MST had higher learning gains than half the control teachers, and all Florida teachers who used MST had higher learning gains than approximately two-thirds of the Controls. Other analyses detailed in SRI International and University of South Florida St. Petersburg (2010) indicates that MST is effective regardless of student ethnicity or prior math knowledge.

Figures 1 & 2: Texas Pretests and Gain Scored Compared to SunBay Math.



Discussion: Infrastructure First

Proposals to improve U. S. schools commonly emphasize the importance of increasing capacity *before* change occurs in classrooms. The logic of that approach appears to be that if only districts and schools would hire higher quality teachers, create coherent systems of assessment and instructional guidance, improve the practice of local leadership, or engage in sustained content-aligned PD, then classroom teaching might improve (e. g. Bryk, Camburn, & Louis, 1999; Desimone, Porter, Garet, Yoon, & Birman, 2002). SunBay Math illustrates an alternative approach, in which classroom practice is improved as a first step in increasing district capacity. Using resources available in almost any U.S. district—3 days of summer PD, monthly trainings, technical assistance from a college of education, and a well-researched replacement unit—the partners were able to effectively increase student learning in core content specified by state standards. Our findings show that, within this approach, MST was highly robust. Teachers used MST in classrooms in which every student had a net-book computer, and teachers used MST in classrooms in which the SimCalc MathWorlds software was projected on a screen from a laptop students never touched. Even the SunBay Math teacher with the lowest gain scores outperformed more than 66% of the control teachers in Texas, and 6 SunBay Math teachers outperformed the top 99% of the Texas Controls. Rather than waiting for a pool of reform-oriented teachers to develop in order to achieve the goals outlined in current national mathematics standards, SunBay Math is using infrastructure from SimCalc and a college of education to build this capacity one teacher at a time.

Endnotes

(1) Co-first authors.

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