Evaluating Teacher Perceptions of the SimCalc Connected Mathworlds Intervention

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This report was conducted under contract with the James J. Kaput Center for Research and Innovation in STEM Education in Fairhaven, Massachusetts. This work would not be possible without considerable cooperation from the Kaput Center Director, Dr. Stephen J. Hegedus, Kaput Center staff, Sara Dalton and Arden Brookstein, and from teachers at the participating schools in Dighton-Rehoboth, Rochester, Wareham, New Bedford, Dartmouth, and Westport that were part of the SimCalc study.

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# Contents

- **Introduction** 3
- **Background** 4
- **Data Collection and Analysis** 5
- **Findings** 6
  - Perceived effect on teaching ............................................................... 6
  - Perceived effect on student learning ..................................................... 7
  - Influence of SCM on student engagement and communication ............. 8
  - Impact and success of the intervention curricula ................................... 9
  - Use of technology for enhancing the learning environment ................... 11
- **Implications** 12
- **References** 13
- **Appendix A: Questions for semi-structured interviews** 14
  - Major Themes .............................................................................................. 14
  - Focus Group Questions ............................................................................. 14
Introduction

This report is the first of two studies that utilize teacher interview data to explore perceptions of the SimCalc intervention described in the Institute of Education Sciences (IES) grant *Democratizing Access to Core Mathematics Across Grades 9–12*. This first report focuses on analysis of teacher interviews from an evaluative point of view. It examines progress on five important dimensions of the intervention that were identified before data were gathered:

- Perceived effect on teaching
- Perceived effect on student learning
- Impact and success of the intervention curricula
- Influence of SimCalc Connected Mathworlds on student engagement and communication
- Use of technology for enhancing the learning environment

The focus of the upcoming second report, *Viewing Teacher Perceptions of the SimCalc Intervention Using the Opportunity to Learn Perspective*, reflects themes that have emerged from the interviews without regard to the initial focus of the inquiry. This next study is centered on the relationship between the intended curriculum and the implemented curriculum (McDonnell, 1995) as reported by teachers in the SimCalc intervention. This second report explores the way curriculum design interacts with teacher experience and disposition.
Background

The SimCalc Connected Mathworlds (SCM) began its life as a 1993 National Science Foundation grant to develop “cybernetic manipulatives” to help students understand complex mathematical ideas, and was first described by Roschelle and Kaput (1996). SimCalc,

“…allows students to create mathematical objects on graphing calculators and see dynamic representations of these functions through the animations of characters whose motion is driven by the defined functions. Students are then able to send their work to a teacher’s computer. Calculators are connected to hubs that wirelessly communicate to the teacher’s computer via a local access point. The flow of data around a classroom can be very fast allowing large iterations of activities to be executed during one class.” (Tapper, Brookstein, Dalton, Beaton & Hegedus, 2009, p.1)

Since it began in 1993, there have been numerous upgrades to SimCalc software and curricula. These improvements have focused on the utilization of SCM as a tool for promoting deeper conceptual understanding of algebra concepts of change and variation, engaging students in meaningful mathematical communication, and providing access to the powerful ideas of algebra to a wide variety of students (Ares, Stroup & Schademan, 2009; Hegedus & Kaput, 2003; Hegedus & Moreno-Armella, 2009; Kaput, 2003).

In 2006, the IES funded a $1,979,295 study on implementing SCM as a replacement unit for sections of Algebra 1 and Algebra 2 courses dealing with functions, change, and variation. Curricula for both interventions were developed at the Kaput Center for Research and Innovation in Mathematics Education (the Kaput Center) and implemented in a number of public schools in Southeastern Massachusetts. At the time of this report, data from the Algebra 1 intervention had been gathered for two years (pilot year, and first year of full implementation) and for one year (pilot year) for Algebra 2.

The Democratizing Access to Core Mathematics Across Grades 9–12 (the SimCalc study) gathered data to pursue research questions related to mathematics teaching and learning, to student motivation, and to communication and engagement in a connected classroom. Cluster randomization provided the study with randomly chosen classrooms for the intervention and for comparison. Survey and assessment data were gathered on mathematics learning (pre and post), student attitudes, teacher characteristics, and reported teaching practices. In addition, hundreds of hours of video data were gathered to explore student interactions, communication patterns, the effects of connectivity, gestural analysis, and other qualitative questions. Analysis of these data is ongoing, as two more years remain for grant funding. Focus group interviews were conducted with every teacher who participated in the SimCalc intervention during the 2008–2009 school year to collect his/her impressions of SimCalc and to assess the perceived impact of the intervention.
Data Collection and Analysis

Teachers who participated in the SimCalc study as intervention teachers were interviewed individually or in pairs in May and June of 2009. Comparison group teachers were not interviewed. Interviews were semi-structured (see Appendix for interview questions) and focused on the teachers’ perceptions of SimCalc effects on their teaching, student learning, student engagement and communication, and technology use. Fourteen teachers were interviewed at eight different schools. All but one of the teachers conducted the intervention in a high school. One respondent worked with a group of eighth grade algebra students. One respondent taught in a technical high school. The schools ranged from rural to urban settings, with the majority of schools in suburban towns.

Comparative analysis was used to contrast teacher experiences and to find emerging themes within the data. For the purpose of this study, the group of interviewees was treated as a single case linked by exposure to professional development in the SimCalc curriculum, by geographical proximity, and by a common goal of implementation.
Findings

Perceived effect on teaching

Almost all of the teachers interviewed disclosed that SimCalc had an impact on their teaching. All but two of the respondents reported that using SimCalc moved them toward more active teaching, and moved them toward what Cobb (1992) calls a “constructivist view of mind.” Interviewees had varying reactions to this change in teaching stance, but several reported that what SimCalc asked of them was different than their usual role as teacher:

INTERVIEWER: So was your teaching any different when you used the SimCalc?
TEACHER: Well, yeah, very different.
INTERVIEWER: Very different?
TEACHER: Very different … because you wanted to try to make it more discovery for them… I felt that I, in order to be productive, I kind of had to do a little guiding too at the beginning.

SimCalc pushed me to be more of a guide than a presenter of information. I did more investigation/inquiry with SimCalc than in other classes.

I like that—going from table data to the real world and making those connections. So, question by question, (in my opinion) they were being led toward certain conclusions—rather than, “Hey here is what you are going to see,” or “Let me show you an example and now you mimic what I just did,” very different.

I liked it (SimCalc) for the way I like to teach. It allowed for deep understanding… I like doing it in a discovery type of way. (parentheses added)

During the interviews the teachers were asked to situate themselves on a continuum of mathematics teaching practice. At one end of the continuum was a representational view of teaching: that the primary task of the teacher is to present students with mathematical concepts and procedures, and to have students practice these by replicating the teacher’s work. At the other end of the continuum is the view that the role of teachers is to help students construct their understanding: that learners build their understanding from experience and interaction with others. All but one teacher situated themselves in the middle of the continuum, but comments during the interview suggested that their perceptions might be different than their practice:

If you don’t tell students what to look for, you won’t have enough time to cover the concept.
I am a “teach, practice” teacher in algebra.
The kids need to follow the steps.
I normally show students how to get the formula—how to find the change in y over the change in x. I show them how to find the slope.
Interviewees tended to situate themselves in the middle of the proposed continuum despite evidence that most inhabited the representational end of it. Yet all of the teachers interviewed reported that using SimCalc moved them toward the use of a more constructivist view. Several teachers suggested that SimCalc worked “in reverse” of their other math programs. Where textbook programs began with skill development and then applied the new skills to problem solving contexts, SimCalc began by developing concepts through problem solving. There was some disagreement among respondents about whether SimCalc ever taught skills, but there was consensus that SimCalc helped students create concepts through focused experiences and communication of understanding.

**Perceived effect on student learning**

Teachers reported a perceived impact from SimCalc in three areas:

- They believed that SimCalc created a useful model for students to understand slope and velocity.
- They reported some concern from students that they were not learning “real algebra.”
- Some of the interviewees suggested that students generalized algebra concepts well as a result of their involvement with SimCalc.

There was consensus among the interviewed teachers that SimCalc was highly effective in creating a robust model for slope. Teachers reported that students came to think of slope as “position/time,” and y intercept as “initial position”:

- We did a project (in my other classes) where we were looking at x=0. They had a really hard time with that. The SimCalc class, though, just thought of it as position at time zero.
- They could even say that “zero is something.” This was confusing for the control group.
- Only one of seven groups had any sense that this was the y intercept. The control group got stuck on “zero is nothing.”
- (When working with slope) The values had a meaning all the time. (parentheses added) SimCalc is successful at getting students to think about functions visually.
- Kids look at all aspects of a function really well—algebra, real life, representations.
- I think the SimCalc group did better than my other classes on these concepts. I could tell they understood it better.
- I’m sure that the students understand linear functions and systems that they’ve never understood when I’ve taught it before. And I think I’m a pretty good teacher.

Several of the teachers reported that at least some of their students were resistant to using SimCalc, at least part of the time. Four teachers in different schools reported that students were concerned about learning algebra using SimCalc because it was so different from their usual mathematics experience. In several cases teachers reported that a group of students in their classes had asked to “go back to the book to do real algebra.” Interviewees identified several potential reasons for these attitudes. Some believed that students were simply responding to the difference in pedagogy and materials. Several of the respondents
made the conjecture that student motivation for being in an algebra class is not always to learn algebra. These teachers thought that some students simply wanted to replicate the teacher’s work on their homework assignments and get a good grade for the course. These students, several teachers surmised, were motivated by grades, rather than an understanding of algebra.

*My kids asked me when we were going to get back to real algebra.*

*I had a student that was concerned that she wouldn’t pass MCAS because of this.*

*Sometimes students got frustrated with this. Sometimes they said, “Just tell us how to do it!” This was surprising because our usual curriculum is very problem based.*

*By the end of the unit, the kids were saying, “Can we just go back to lecture?”*

A little more than half of respondents said that they observed some transfer of concepts from the SimCalc setting to other settings. In two instances, these were reported as science settings (specifically physics), where students had used knowledge of velocity graphs to predict outcomes of experiments with motion. While not all the teachers agreed that using the SimCalc gave students greater access to concepts in novel settings, there was a strong perception among teachers that this was the case.

*I think the students can see how this is applied in the world.*

*The content of the course should allow students to represent data from the real world.*

*There were times during an investigation when someone would explain his understanding and I’d think, “That’s what I’d say if I were going to teach this concept.”*

**Influence of SCM on student engagement and communication**

Providing a rich environment for student interaction is an important element of the SCM design. The technology and curriculum create affordances for student—student communication that might not exist in the regular classroom. Typically, students investigate the motion of actors on their calculators and record graphs of their solutions to problems related to that motion. The teacher has the opportunity to harvest graphs from all the groups (or individuals) in the room in order to share student strategies and solutions.

The act of harvesting student graphs and asking students to discuss them with the class is an activity that begs for high levels of communication, interaction, and engagement. A teacher might, for example, display six different samples and ask students to explain their work, or ask the whole class what they see in the work displayed.

While SimCalc is designed to foster high levels of communication and engagement, not all teachers took advantage of this opportunity. It appeared that reported levels of communication and engagement varied significantly with teaching stance: Teachers who stated a preference for being the sole manager of classroom discourse—lecturing, soliciting responses to their posed questions—reported that they chose specific graphs to display and then showed students what was interesting or important about them. There were two groups of teachers from two different schools represented in this group. These teachers tended to report lower levels of communication and engagement, often saying there was no difference between SimCalc and other classes.
(Engagement in the SimCalc class was) Typical. No different from giving kids problems on a worksheet. (parentheses added)

My class was less engaged. I liked this material better but they liked it less. My class didn’t have the confidence to share any of their thinking. They wanted to be told what to do and just do it.

No difference (overall) in engagement.

In the beginning disengaged kids were more engaged. But after a week or two they returned to bad habits. In the end, engagement wasn’t any different.

By contrast, teachers who reported that they made the experience more “student led” (a respondent’s phrase), that is, they tended to allow students to arbitrate at least some of the discussions and inquiry, reported higher levels of communication and engagement among students.

It gets 100% engagement. In the regular class a portion of the kids don’t bring or use their calculators. It pulled everybody in.

I liked the engagement, especially with these kids. There was lots of prediction related to the graphs—sometimes arguments about what they were seeing.

When all the actors move simultaneously, there is very high engagement. Normally, you don’t get every set of eyes focusing on the same thing.

It was a good group, in terms of feeling secure. There was a lot of willingness to throw ideas out whether they were right or wrong.

There were more opportunities for students to communicate with each other and with me in the SC class.

As you’re going through the lessons students are almost forced to have dialog with you.

Putting graphs up creates a responsibility for communicating. They can’t blindly hide behind taking notes.

Impact and success of the intervention curricula

Two of the themes related to the curriculum that accompanied the SimCalc Mathworlds intervention have been previously discussed: Respondents reported a strong emphasis on the concept of slope as related to velocity as a change in position/time; and intervention teachers indicated that the curriculum emphasized developing concepts as a result of investigation.

Additionally, interviewees reported a perception that the activities in the curriculum were too repetitive and that students were sometimes bored with the repetition. They also reported a concern about the frequent use of the slope-intercept form of the linear equation.

It started out feeling really new. But by the end it was feeling very old.
The kids would complain about “another one of these.”

The activities were, maybe, a little too repetitive. It could have been streamlined a bit.
The class thought that the activities were repetitive. They didn’t see how the activities changed.
Overall it went well. Some of the activities were a little repetitive.

There was a perception, among some of the participants, that the SimCalc intervention had left gaps in curriculum. Five of the respondents believed that there were important topics that had not been covered. This particular finding is somewhat confounded by the information that these same teachers gave about the most important topics in algebra and their relationship to SimCalc. For instance, teachers reported with some consensus that understanding functions, slope, and systems of equations were the essential elements of Algebra 1. Teachers almost universally recommended SimCalc as unusually effective for developing conceptual understanding in these same areas. This apparent contradiction begs the question of what teachers believe “covering” a topic involves. Perhaps teachers, like the students, were not entirely clear that the learning taking place with SimCalc was an alternative method for understanding key mathematical content.

INTERVIEWER: Ok so what did SimCalc keep you from getting to that is essential?

R1: I think... I am going to try and phrase it too. We got to the multiple representations which would be the graphing, the tables and so forth, and the function. But, I still think there are other ways, I don’t know.

R2: Well just for example getting an equation in slope intercept form kids have such a hard time manipulating an equation and they didn’t get all that practice. It was always y=mx+b all the time, you know? That was just one big, writing equations of lines again. It was mainly starting point velocity. So they never really...

R1: Right they were given slope and intercept and they got pretty quickly what slope and intercept were... But not enough, (I didn’t think) of maybe just, here’s some data. Not enough of it. There was some of it but there wasn’t enough of, here’s some data how would you represent that as a line? How would you represent that as a group?

There was a lot of algebra that didn’t get taught. I threw in completing the square, the quadratic formula, vertex form, because they weren’t covered.

There isn’t enough meat in the curriculum. You’re only looking at pieces of the function (first quadrant) that exist in the real world. The investigations were so open-ended, I don’t think the kids put it all together. If I gave them a velocity function, they could say, “it has a negative slope.” But they couldn’t put the data back into the position function. They didn’t see the position function in its entirety.

There was a consistent concern about the ability of students to write equations in forms other than slope-intercept. When questioned about the possibility of using algebra to transform $y=mx+b$ into standard form, three of the respondents said they were convinced that without practicing the standard form, students would be unable to make the connection between the two forms of the equation.

The concern about the standard equation form was similar to other comments about “skills” that teachers were concerned students weren’t getting. Other than using the standard form of a linear equation the only skill that teachers mentioned explicitly that was missing from the curriculum was completing the square. Teachers who believed quadratics or polynomials were essential concepts for Algebra 1 tended to mention the absence of exercises on completing the square.
Use of technology for enhancing the learning environment

Technology is a major component of the SCM intervention. There is a common perception among respondents that it helps students to build usable models for understanding motion. Teachers report that SCM may give students a vehicle for conversation by creating products of their investigations. They also suggest that the use of technology allows students to share their complex mathematical thinking in public spaces.

Respondents made many comments about the technology that fall into two broad categories: constraints, i.e., experiences with technology that limited engagement and understanding; and affordances, i.e., experiences that supported learning. Constraints that interviewees reported tended to focus on technical issues and setup. Affordances included the many ways that SimCalc improved teaching and learning for students.

**Constraints.** Four of the respondents reported that they had some significant issue with hardware. All reported that the Kaput Center staff was responsive and worked quickly to help them move forward with SimCalc. One interviewee abandoned his use of the technology altogether after using it for a short period of time.

Several teachers reported that setting up the calculators and connectivity hardware was difficult. One said that he missed his lunch break daily to set up the system. Another told me that the setup was a burden, but she was willing to take it on in order to benefit from the connectivity the system provided. One of the teachers commented that she had the students do the setup at the beginning of class. Others had made attempts to have students set up the equipment but worried about calculators being damaged or disappearing.

Several participants suggested that the use of SimCalc in a dedicated lab committed to that purpose would have solved most of the challenges with setup. The suggestion was also made to house classes using SimCalc in a computer lab and make use of the program on a PC, rather than a calculator. This was seen (by the two teachers who suggested it) as a potential improvement in both connectivity and graphics quality.

**Affordances.** All the teachers interviewed appreciated the opportunity that SCM provided for modeling slope and for sharing student work. While the use of graphing calculators was only common (outside of SimCalc) in two settings, every teacher, except for the individual who gave back his equipment, commented on the value-added nature of the SimCalc technology. His difficulties with the technology were less about the equipment itself as much as the setting in which he was using it.

> Using SimCalc was different because the kids are linked together. They do more than any kid could do individually.

> (Using the technology) there were more opportunities for students to communicate with each other and with me in the SC class. As you're going through the lessons students are almost forced to have dialog with you. (parentheses added)

> The connectivity of SC makes it different from working with just graphing calculators.

> SimCalc is technology done right.
Implications

Perceptions of the SimCalc intervention program, as reported by teachers in the intervention group in the spring of 2009, include an appreciation for the role that the curriculum and technology play in enhancing student learning in algebra. Teachers reported that SimCalc was particularly successful in helping students to build a robust conceptual model of slope. Teachers also suggested that many of their students were more deeply engaged in mathematics learning and in communicating their mathematical understanding as a result of their experience with SCM.

In addition to the affordances that teachers reported with SimCalc, concerns were raised about the perceived repetitiveness of the curriculum and the effectiveness of its use of constructive learning. Future investigations of the SimCalc intervention might focus on whether these perceptions, or others reported here, change over time or with greater program use.

Overall, interviews with these fourteen teachers left the impression that there were divergent understandings of the design of the curriculum, the content goals of the intervention, and the pedagogy for successful implementation. When teachers’ understanding, goals, and pedagogy were consistent with the intents of SimCalc, they generally found the program to be helpful and that their students benefitted from it.

On the other hand, when teachers approached the intervention with diverging views from the curriculum design and/or pedagogy, the implementation was not very different from the everyday algebra that SimCalc replaced. In the greatest of these mismatches, teachers (and through them, reports of students) seemed to feel that SimCalc was not beneficial. Whether this dichotomy could be remedied through further professional development or by varying teacher selection is an area for further investigation.


Appendix A: Questions for semi-structured interviews

SimCalc Interviews

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Major Themes

- Impact on instruction
  - Changes in approach to content
  - Changes in approach to pedagogy
- Perceived impact on learning
  - Conceptual understanding of key ideas from Algebra 1
    - Ability to generalize ideas to new mathematical situations
    - Demonstrating “beyond taught” understanding
  - Procedural competence
    - Use of key formulas and algorithms (quadratic formula, slope-intercept, etc)
    - Demonstrating understanding of important procedures
- Perceived impact on communication and engagement
  - Impact on the development of mathematical ideas
  - Impact on the development of personal theories or thinking
  - Perceived engagement
  - Perceived changes in motivation
- Use of the curriculum
  - Perceived effectiveness of the curriculum
  - Perceived comprehensiveness of the curriculum with regard to Algebra 1
  - Assessment in the curriculum
- Use of technology
  - Approaches to use
  - Advantages of using technology
    - Value added
    - Challenges to using technology

Focus Group Questions

- Impact on instruction
- How would you describe teaching with SimCalc?
- Has using SimCalc influenced the math content you use? In what ways?
- If you notice differences, how is your teaching practice different when you’re using SimCalc as opposed to when you’re not?
- Perceived impact on learning
- Some math educators, NCTM for example, have defined conceptual understanding as the ability to generalize learning to new situations and to use a concept beyond the initial
examples a teacher uses. Can you give examples from any of your classes where you observed this level of understanding?

- Are there ways in which SimCalc helps foster conceptual understanding of algebra concepts? If there are, can you give examples?
- Algebra uses important algorithms and formulas to compute solutions. The quadratic formula and the slope-intercept formula are two examples. Has SimCalc had an impact on understanding and using algebraic procedures and algorithms? Can you share instances of this?
- Perceived impact on communication and engagement
- Does the use of SimCalc support the exchange of mathematical ideas in your classroom? If so, in what ways?
- Some researchers have suggested that good math instruction can foster a “mathematical community” where ideas are exchanged freely. Has SimCalc contributed to the creation of such a community in your classroom? In what ways?
- For mathematical communication to flourish students must freely share their private thoughts in the public space of the math classroom. Beyond what you normally do to create a supportive environment for sharing ideas, have you noticed that SimCalc has supported students to share their private thinking publicly in any specific ways?
- How do you gauge students’ engagement in your math class?
- Do you notice any differences when you’re using SimCalc?
- Can you give examples?
- In what ways has SimCalc changed student motivation in your classroom?
- Use of the curriculum
- What, do you think, are the most important concepts for students to learn in Algebra?
- Has using the SimCalc curriculum added to your algebra program? In what ways?
- How thorough is the SimCalc curriculum for covering key concepts in algebra when you compare it with your usual curriculum?
- Compare the information you get to support your teaching from SimCalc assessments and the assessments from your usual math program.
- Use of technology
- Does SimCalc add to your usual use of technology?
- Can you remember any instances of using technology enhance the study of algebra when you’re using SimCalc?
- What challenges have you encountered in using technology in the SimCalc program?