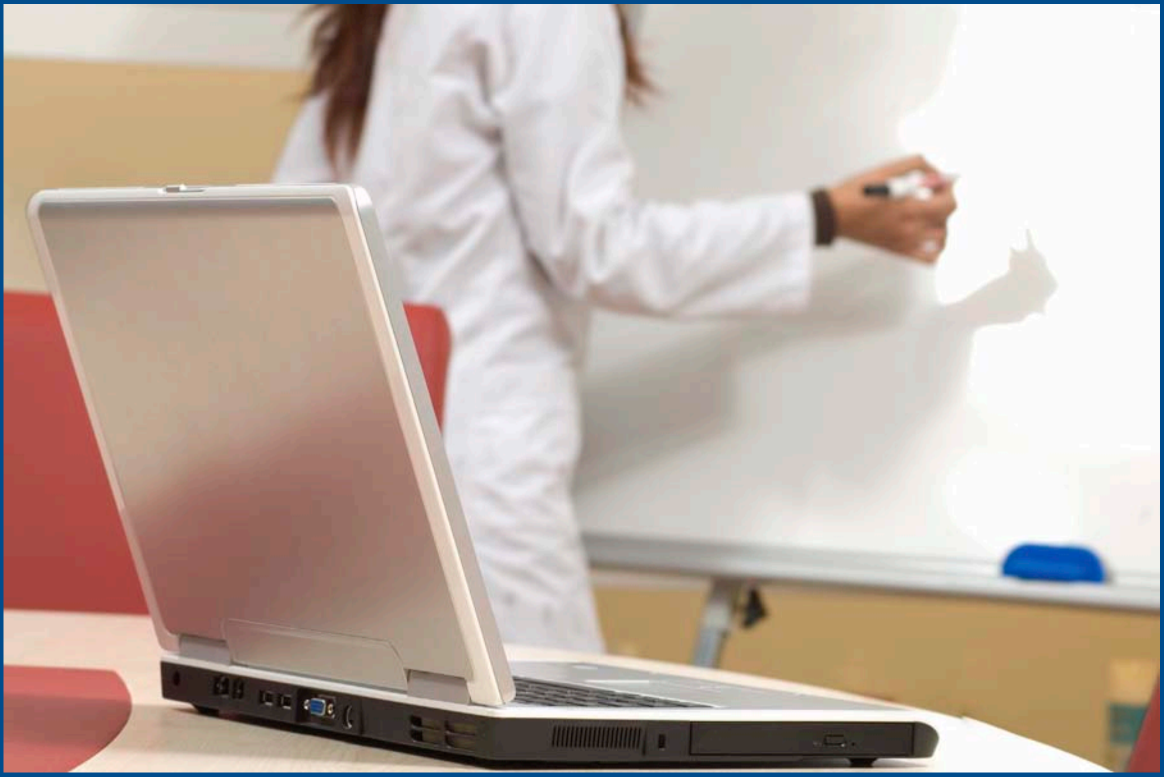
Scaling Up SimCalc Project

What happens when the research ends?

Factors related to the sustainability of a research-based innovation



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What happens when the research ends?

Factors related to the sustainability of a research-based innovation

We explore the potential sustainability of a technology-infused classroom-based mathematics curriculum intervention called SimCalc Mathworlds®. The research reported here took place 1 year after the completion of a multiyear experimental study of the impacts on student learning of a replacement unit designed for middle school mathematics. At that time, 53% of teachers were continuing to use the materials. The goal of this research was to identify factors related to teachers' continued use of SimCalc. The findings are based on teachers' perceptions of the intervention itself and the context in which they operate, which we posit are related to the potential sustainability of the intervention and may speak to the larger question of what makes curricular innovations sustainable. Factors related to sustained use of the intervention were student SES, student mathematics capability prior to the intervention, the perceived coherence and value of the intervention, and the interactive nature of the professional development.

Theoretical Framework

Researchers have made steady progress in developing educational interventions that combine curriculum materials in mathematics and science with integrated technological tools and teacher training to foster improved learning of standards-based content and to develop connections from grade-level content to mathematics that will remain important throughout students' lives. These interventions have been called *coherent curricula* (Roseman, Linn, & Koppal, 2008) or curricular activities systems (Roschelle et al., under review), and they are the products of collaborations between researchers and practitioners developed over multiple iterations of design, development, and evaluation (Blumenfeld, Fishman, Krajcik, Marx, & Soloway, 2000; Cobb, Confrey, diSessa, Lehrer, & Schauble, 2003). In mathematics such materials, in the form of replacement units, have been tested in rigorous experimental studies and shown to be effective in supporting student learning of complex mathematical concepts. This study focused on one set of materials, the SimCalc Mathworlds replacement units for 7th- and 8th- grade mathematics (Roschelle, et al., 2007), hereafter referred to as SimCalc or SCMW. Below, we address several issues that result when such coherent curricula move from research and development into production. Then we discuss possible factors that might facilitate or inhibit the sustainability of curricular innovations, in particular perceived coherence and perceived value. We operationalize sustainability as the continued use of the SimCalc Mathworlds intervention in a manner consistent with its designed intent.

An ongoing challenge to the success of interventions like SimCalc is to create changes in classroom practice that are sustainable, meaning that the teacher continues to use the intervention in the manner intended by its designers and makes moves to own it such that it becomes a regular part of the instructional repertoire and does not remain a special departure from normal practice (Coburn, 2003; Fishman, 2005). Part of the challenge is due to the diminished support associated with the completion of research: In hothouse research environments, support, funding, and encouragement are plentiful, but in everyday practice, teachers and schools have limited access to ready support for innovations and are subject to multiple competing demands (Fishman, Marx, Blumenfeld, Krajcik, & Soloway, 2004). In their planning and enactment, teachers must make choices about the continued use of innovative materials within their existing support structures and within the policy environment that includes items such as standardized high-stakes assessment. The development of educative curriculum materials (Davis & Krajcik, 2005; Ball & Cohen, 1999) represents one effort to embed the core ideas of curricular reform within curriculum materials, a potentially important move toward shaping teachers' practice away from the immediate influence of developers. But the field is still early in its understanding of how such materials should be designed, and the more complex the teaching (e.g., inquiry vs. direct instruction), the more difficult it appears to be to communicate those core ideas in printed materials. Related work is being conducted on curriculum adaptation, attempting to understand how and why teachers adapt curriculum materials to their local contexts and to provide tools to shape adaptation to maintain consistency with designers' intentions (Lin & Fishman, 2006).

As interventions move beyond the immediate involvement of their developers, shifts in practice or "lethal mutations" often occur such that the intended meaning and structure of the original materials are lost (Brown & Campione, 1996). When coherent curricula are implemented in ways that are at odds with their original design, predictions of student learning outcomes based on the original validation research are no longer valid. It is possible, of course, that implementations at great variance with the original design can lead to successful student learning, but we argue that outcomes of such implementations are a function of the individual teacher and context more than any particular characteristics of the materials, and our goal is to develop materials and interventions that lead to reliable learning outcomes across a range of implementation contexts. These implementation challenges are a critical hurdle in the progress of education reform (Penuel & Means, 2004; Rogan, 2007; Rowan & Miller, 2007). Below, we review prior research that we find informative with respect to implementation of curricular innovations. We organize our review into categories or factors that we explored in this study, namely, teachers' expectations for their own students, teachers' perceived coherence of the innovation, and teachers' perceived value of the innovation.

Teacher Expectations and Math Instruction/Achievement

Apart from factors that are either intrinsic to an innovation or attributed to interventions by teachers, there is reason to believe that teachers' perceptions of their own students' mathematics ability shape the kinds of instruction they think appropriate and are willing to enact. There is evidence of a relationship between expectations and achievement, as was found in the 1988 National Education Longitudinal Study (Rowan, Chiang, & Miller, 1997). Analyses of survey data collected through the Third International Mathematics and Science Study (TIMSS) indicated that a distinguishing feature of U.S. teachers is their belief that conceptual teaching strategies in mathematics are more appropriate for high-achieving students than for low-achieving students (Desimone, Smith, Baker, & Ueno, 2005). This aspect of teacher belief is particularly troubling when linked to the "Matthew Effect," a reference to the Gospel according to Matthew where it is lamented that "haves" tend to get more and more while "have nots" tend to lose what little they have to begin with. Such an effect has been documented in various areas of education (Walberg & Tsai, 1983; Stanovich, 1986), including mathematics (Young-Loveridge, 2005). Developers of curricular innovations would want to be especially attuned to this type of effect, as it could explain a component of teacher decision making about whether materials are a good fit for their students and thus whether they would choose to sustain the use of a particular innovation.

Studies have also found a strong relationship between teachers' beliefs about who should be in control of mathematics activity in the classroom and the nature of mathematics ability and mathematics instruction (Stipek, Givvin, Salmon, & MacGyvers, 2001; Wilkins, 2008). Even when teachers do believe in the potential value of conceptual teaching in mathematics, they often perceive that standards and accountability pressures make it difficult for them to implement these strategies with students (Bolden & Newton, 2008), a phenomenon that we discuss further below as contributing to the construct we refer to as perceived coherence.

Perceived Coherence

One way to describe teachers' perceptions of an innovation is in terms of the innovation's coherence. The first two authors explored coherence in relation to teachers' perceptions of professional development for a K-12 science education reform curriculum called GLOBE (Penuel, Fishman, Yamaguchi, & Gallagher, 2007). Our first explorations of coherence were inspired by the study of Eisenhower Math and Science professional development, in which it was found that professional development programs were more effective when viewed as part of a "coherent program" (Garet, Porter, Desimone, Birman, & Yoon, 2001, p. 927). Garet et al. (2001) constructed their model of coherence on the basis of connections between the professional development and other activities, alignment with state and district standards, and the extent to which teachers participated in groups. In the GLOBE study, we examined a confluence of factors that we hypothesized would be related to how teachers perceived the coherence of the professional development, on the basis of findings from literatures related to policy and practice in teacher learning and reform. This included findings that teachers use their own interpretative frames when making sense of how the messages in an intervention relate to the policy demands (state and local standards) placed upon them (Coburn, 2004; Cuban, 1986; Cuban, Kirkpatrick, & Peck, 2001). Research on the implementation of particular curricular materials showed evidence that school context plays a key role in how teachers decide either to enact or reject particular innovations (Rivet, 2006). Is the innovation consistent with messages from the school or district administration? What challenges (or opportunities) are presented by the local school population? If teachers perceive the innovation to be coherent or congruent with their own or their school's goals for reform, this should lead to an increased commitment to enact the innovation.

In the Penuel et al. (2007) study of GLOBE, we found that perceived coherence was related to observed levels of implementation of the curriculum. Note that in the GLOBE research we were not studying sustainability, but rather initial levels of implementation after professional development. However, there is good reason to believe that implementation is a necessary precursor of sustainability and that the same issues related to coherence would be at play. In this study we turned our attention to coherence as expressed by teachers after the curriculum was initially implemented and asked them to reflect on how the features of the entire intervention (curriculum and professional development and subsequent support) are related to their perceptions of coherence relative to the same factors we explored for GLOBE professional development). We hypothesized that increased coherence should lead to increased sustainability in the current study.

Perceived Value

Teachers' values related to student learning, instructional practice, and their own professional learning may also influence how they perceive an instructional innovation. Friedman and Freier (2005) described an approach to "value sensitive design" that attempted to place these concepts in the foreground. They theorized that values impact behavior, including decisions about whether to enact or continue to enact curriculum materials. We conceptualize value as a set of personal perceptions about the likely benefit of an innovation. For instance, in mathematics education the ability to read graphs is an important learning outcome, featured in standards, and so curriculum materials that teachers perceive as helping their students better understand graphs may be viewed as valuable and therefore worthy of using. What distinguishes learning about graphs as a value as opposed to a component of coherence is the worth a teacher places upon it. Learning how to read graphs might be specified in standards (we described alignment with standards as a component of coherence above), but if a teacher feels that she or he is already meeting that standard in another way, the value added by the new curriculum innovation might be low. A social norm emphasizing the use of technology might also drive value, such that an innovation like SimCalc that embeds technology use in the curricular activities is viewed as providing a valued outcome beyond "regular" content learning. Teachers might also value innovations that make their lives easier. Innovations that are highly specified (Cohen & Ball, 1999) help reduce the amount of decision making by teachers. This could be viewed as valuable for some teachers who appreciate the ready-made character of the materials, but other teachers may see these innovations as less valuable because they reduce their autonomy. Providing lesson plans or support for lesson planning could also appeal to teachers as valuable because many teachers are required to provide lesson plans as part of administrative oversight: In fact, one reason why the replacement unit strategy for scaling has become so popular may be because in part it adds value from teachers' perspective.

Value is also likely to have both general and specific dimensions. For instance, there are some elements of planning that are specific, such as information about how lessons are related to standards, guides for organizing student activities, provision of worksheets, readers, or other materials. These are general features of curriculum materials that teachers could see as valuable. Specific innovations, such as SimCalc, might have unique features for which specific support is required. For example, few replacement units in mathematics require the extensive use of technology. The fact that SimCalc does require the use of technology for a successful implementation may mean that teachers will value SimCalc more only if the professional development or other support materials provide them with sufficient support for technology or other specialized aspects of the SimCalc innovation.

Methods

This mixed-method study focused on the 7th- and 8th-grade teachers who participated in a prior large-scale randomized trial of the efficacy of the SimCalc Mathworlds curricular activity system. The prior study is called "Scaling Up SimCalc" (hereafter Scaling). The present study was correlational in nature, focused on identifying associations between school- and teacher-level variables and persistence (or sticking) with the SCMW curriculum. In the Scaling experiment, teachers were recruited by local education service centers, were provided with all necessary materials including computer software, and were paid a stipend for their participation. Results from the Scaling studies (presented elsewhere) indicated that students of teachers who implemented the 2- to 3-week replacement unit on rate and proportionality performed as well on basic-level test items as students in control classrooms and much better on challenge items, indicating a deeper understanding of the math concepts (Roschelle et al., 2007). The full intervention consisted of a professional development workshop that presented 3 days focused on SimCalc and a follow-on planning meeting during the school year, printed curriculum guides with student and teacher materials, and software to help students visualize concepts such as rate versus time and proportionality. This paper does not focus on results of the Scaling study (see Roschelle et al., under review), instead using that study and its participants as a context to understand what happened next, after the Scaling study was concluded. The research reported here is part of a larger effort related to the diffusion of SimCalc Mathworlds being directed by the Kaput Center at the University of Massachusetts at Dartmouth.

Data Sources

Data for this study came from two sources: (1) an online survey administered to teachers in 2008, approximately 1 year after the conclusion of the Scaling experiment, and (2) pre- and posttest data from the Scaling study from 2005-2007. The survey consisted of 15 items, focused on teacher perceptions of professional development, support for implementation, barriers to implementation, continuing use of the intervention materials, and communication with peers relating to the intervention materials. Many of these items were validated in prior studies of teacher professional development (Garet et al., 2001), implementation, and the scaling up of innovations (Fishman, Penuel, & Yamaguchi, 2006; Penuel et al., 2007). Prior uses of the survey items were for generic professional development contexts in math and science and for a specific, but different set of curriculum materials. Consequently, we slightly adapted the items to address the specific context of the Scaling study. In addition, some new SimCalc-specific items were created for this study. The survey was piloted over the telephone both with teachers in Texas and with users of SimCalc in other parts of the country in order to determine that the items were comprehensible and being interpreted in the manner we intended.

Sample

The sample population for this study was the 189 teachers who participated in the original SMWC Scaling study. Seventy-six teachers from the larger population responded and completed an online survey, for a response rate of 40%. Of survey responders, 77% were female ($n = 51$), and 23% were male ($n = 1$); they ranged in age from 27 to 59 ($M = 43.47$, $SD = 9.073$) and represented between 1 and 27 years of teaching ($M = 10.87$, $SD = 7.413$) and 1 and 27 years of teaching mathematics ($M = 9.64$, $SD = 6.867$).

We conducted a nonresponse analysis to determine whether the teachers who responded to our survey differed in any meaningful way from teachers who did not. Using independent-samples t tests, we compared initial student scores ($t = -1.647$, df = 145, $p > .05$), gain scores from pre-post testing ($t = -.772$, df = 146, $p > .05$), the geographic distribution of teachers (data from the original experiment) ($t = 1.516$, df = 178, $p > .05$), and campus-level SES ($t = -.371$, df = 146, $p > .05$). None of these comparisons indicated a significant difference between response and nonresponse groups, giving us confidence that the results of this study were not biased as a result of response patterns.

Measures

The following items and scales were developed in our analysis of the surveys.

"Stick"

A single binary (1 = yes, 0 = no) item on the survey served as our measure of sustainability, or sticking with SCMW after the end of the SimCalc Scaling Study: "Are you still using all or part of the SimCalc curriculum?"

Student Socioeconomic Status

We used the percentage of students in the teacher's school who were eligible for free or reduced-price lunches as a measure of students' socioeconomic status.

Prior Mathematics Achievement of Students

We used as a baseline the normalized pretest scores of students in the SimCalc Scaling study on the tests of mathematics achievement developed by the SCMW research team (see, Roschelle et al., under review, for an extended description of the measure and its development). This test was constructed to measure both the more formula-oriented and procedural aspects of proportionality and linear function, as conventionally measured on the Texas statewide assessment, as well as a function-oriented and conceptual orientation to these topics. For example, the test asked students to consider the mapping between a domain and range and to connect such concepts as rate across multiple representations (e.g., k, in $y = kx$ and the slope in a graph of $y = kx$). The scores used were those of students from teachers' classes that had participated in the SimCalc Scaling study (in a prior year) and were not scores of teachers' students at the time we conducted the survey (after the experiment had concluded). To the extent that students across years have similar levels of ability, however, the pretest scores do offer a proxy measure of prior achievement levels of students, particularly with respect to conceptually rich mathematics.

Perceived Coherence

We incorporated into our questionnaire a six-item scale ($\alpha = .93$) used in three earlier studies of professional development (Garet et al., 2001; Penuel, Fishman, Gallagher, Korbak, & Lopez-Prado, in press; Penuel et al., 2007), which measures how well the professional development matched the teacher's goals for professional development, the existing reform ideas within the school, and whether the professional development was followed up with activities that built on what was already learned. In this study, we used perceived coherence as a teacher-level predictor of sticking with SCMW.

Perceived Value: General

The perceived value scale is a three-item scale ($\alpha = 0.84$) that measures teachers' perceptions of the value of SCMW materials. We refer to it as a general scale because it encompasses items that teachers are likely to consider in assigning value to curriculum materials, regardless of the particular materials: the value of the print materials, the timetable for enactment, and support for teaching required standards. For each of these items, teachers indicated whether they found SCMW materials *very valuable*, *valuable*, *not so valuable*, or *detrimental* for their teaching. The scale created represents the sum of the three items.

Perceived Value: SimCalc Mathworlds Key Features

The perceived value scale for key features of SCMW is a three-item scale ($\alpha = 0.94$) that measures teachers' perceptions of the value of features judged by program developers to be key features of the software. These key features are simulations, interactive graphs, and the tight integration of curriculum and technology. As with the other value items, for each item teachers indicated whether they found these key features *very valuable*, *valuable*, *not so valuable*, or *detrimental* for their teaching. The scale created represents the sum of the three items.

Interactive Professional Development

The interactive professional development scale is a three-item scale ($\alpha = 0.94$) that asked teachers to report how much interaction took place as part of their professional development to learn to use SCMW materials. The SCMW development team identified these items as key features of SCMW and "active learning" in professional development activities has been linked in other studies to reported changes in teacher outcomes (Garet et al., 2001; Penuel et al., 2007). This scale is thus a combination of items that are generally related to effective professional development for curriculum implementation and items that SCMW developers believe are particularly important for implementing their curricular activity system. For these items, teachers rated items on a six-point scale from *did not participate* to *found essential* in preparing to teach the SCMW unit.

Approach to Analysis

Our primary interest was in analyzing what factors are associated with teachers' decision to stick with SCMW after the study ended. Because of the small sample size and also because our predictors were highly correlated (see Table 1) with one another, we examined the contribution of each potential factor separately. The advantage of our approach is that it allowed us to consider how each of our theorized mechanisms may have contributed to teachers' decisions to stick. At the same time, the strong, significant correlations suggest that there may be an underlying mechanism that explains the patterns of survey responses we see more adequately than the scales we used in our analysis. We return to this potential limitation of our analysis in the Discussion and Conclusion Sections.

Table 1. Correlation matrix of teacher-level predictor variables.

	(1)	(2)	(3)	(4)	(5)
(1) Students' mean achievement on the M2 Scale (pretest prior to SCMW)	1.00	0.28*	0.18	0.21	0.30*
(2) Perceived Coherence Scale		1.00	0.43**	0.37**	0.96**
(3) Perceived Value Scale: General			1.00	0.72*	0.38**
(4) Perceived Value Scale: SCMW				1.00	0.35**
(5) Interactive Professional Development Scale					1.00

* $p < .05$, ** $p < .01$

Descriptive Statistics

Approximately half ($n = 35$, 53.8%) of the teachers who completed our survey ($n = 67$) reported continued use of the SCMW curriculum materials 1 year after the conclusion of the Scaling Up SimCalc research study. Descriptive statistics for all other measures are reported in Table 2.

Table 2. Descriptive statistics.

	n	M	*SD*
School-Level Predictors			
Percentage free and reduced-price lunch	67	50.42	27.16
Teacher-Level Predictors			
Students' mean achievement on the Complex Mathematics (M2) Scale (pretest prior to SCMW)	67	5.29	2.41
Perceived Coherence Scale	66	22.02	4.27
Perceived Value Scale: General	65	9.11	2.20
Perceived Value Scale: SCMW	65	10.03	2.61
Interactive Professional Development Scale	66	6.42	1.90

Findings

Table 3 reports the significance of the factors explored in this study with respect to sustained use of the SCMW curriculum materials. The strongest likelihood of sticking was found in relation to students' SES (d = –0.93, $p < .001$) and students' prior achievement in conceptually-rich mathematics (d = 0.81, $p < .05$). The higher the SES and the greater students' pre-SCMW performance in conceptually rich mathematics, the more likely the teacher was to continue using the SCMW materials. A relationship was also found between sticking and teachers' perceived coherence of the SCMW materials (d = 0.56, $p < .01$). A slightly weaker relationship was found for perceived value, both in terms of general value (d = 0.40, $p < .05$) and for the value of specific characteristics of the SCMW materials (d = 0.37, $p < .10$) and also for the interactive nature of the professional development (d = 0.26, $p < .05$).

Finally, we asked those teachers (*n* = 30) who indicated that they did not continue to use the SCMW materials (i.e., did not stick) to identify reasons that might explain their decision. These reasons are presented in Table 4.

Table 3. Factors related to "sticking" (T tests)

	Stickers	Nonstickers	*t* (df)	d
Percentage free and reduced-price lunch in school (SES)	M = 40.90 *SD* = (25.90)	M = 63.51 *SD* = (24.44)	–3.55*** (61)	–0.93
Prior achievement in conceptually rich mathematics	5.96 (2.67)	4.47 (1.86)	2.53* (61)	+0.81
Perceived Coherence Scale	23.37 (3.04)	20.93 (4.35)	2.65** (63)	+0.56
Perceived Value Scale: General	9.60 (1.56)	8.53 (2.69)	1.99* (63)	+0.40
Perceived Value Scale: SCMW	10.63 (1.33)	9.33 (3.47)	1.93+ (44.9)	+0.37
Interactive Professional Development Scale	6.94 (1.41)	6.03 (3.47)	2.17* (63)	+0.26
+ *p* < .10, * *p* < .05, ** *p* < .01, *** *p* < .001				

Table 4. Percentage of teachers indicating various reasons for no longer using SCMW materials (*n* = 30)

Reason for not continuing to use SCMW materials (not sticking)	Percent
Material took too long, interfered with preparation for state tests	30
Difficulty completing activities in suggested time	27
Lack of time to prepare	23
Lack of technology access	20
Lack of computers in school	13
Interest level of my students	13
Lack of alignment to state test	10
Math knowledge level of my students	10
Difficulty with software	7
Unsupportive district administrators	3
Lack of technology support	3
Unsupportive building administrators	0
Lack of understanding of how to implement units	0

The top three reasons teachers gave for not continuing to use the SCMW materials were related to time (time to prepare for state tests, time to enact the activities, and time to prepare to use the activities). The second most common explanations were related to access to technology (if the school had computers, the SCMW teacher believed access to them was inadequate) or lack of computers overall in the school. We also note that very few teachers reported technical difficulties or administrative support as their reasons for not continuing with SCMW.

Discussion

What can we learn from the findings presented above, and how do they help us further refine our understanding of findings from prior research on factors related to the sustainability of curriculum materials?

Findings with respect to coherence are consistent with previous research, and help us to continue to refine our understanding of this factor and how it relates to teachers' decisions about the continued use of materials. In prior research (Garet et al., 2000; Penuel et al., in press; Penuel et al. 2007), we examined how teachers' perceptions of coherence are related to their implementation of materials. This construct looks across teachers' judgments of how well the professional development matches their own goals for professional learning, how well the professional development (and perhaps by extension the innovation) matches existing reform ideas in their schools, and how well the professional development is followed up on with activities that build on what was learned in the professional development. Our prior studies focused on initial implementation levels. In this work, we focused on subsequent continued use of materials and found that coherence is again related. The continued value of this factor is encouraging and provides further evidence for the importance of constructing professional development activities with the teachers' perspectives about coherence firmly in mind.

This study represents the first time we have examined perceived value directly. In our initial data analysis (not reported here), we considered a monolithic definition of the value construct, but discussion among members of our research team prompted us to break this scale up into both general and SCMW-specific scales. We were interested to see that both scales related to teachers' continued use of the SCMW materials and were further interested to see that the more general notion of value was more strongly related to sticking than curriculum-specific notions of value. This may be an indication that teachers are weighing the value of any particular curricular innovation against an ongoing set of daily challenges, including planning, time to teach, and the demands of standards. The specific qualities of the SCMW materials, namely, tight integration with technology and a focus on interactive graphs and simulations, may be viewed by teachers as important but only within the context of the larger teaching context. We plan to explore this contrast in further analyses.

We now turn to variables that describe teachers' perceptions about fit with either their preferred style of teaching or the capabilities of their students. There was a relationship between continued use of the SCMW curriculum materials and teachers' perceptions about how cognitively complex their math teaching was prior to using SCMW. This is also borne out by data gathered as part of the Scaling study, where teachers of students with more advanced mathematical abilities (as measured by the pretest) were more likely to continue using the SCMW materials after the conclusion of the Scaling study. In some ways this is discouraging, because it suggests that the Matthew effect is alive and well. This clearly represents an ongoing challenge for developers of reform-oriented materials such as SCMW, but our data do not offer suggestions for addressing this challenge.

Conclusion

Working to develop innovations that are usable and, more important, continue to be used by teachers is a critical challenge for the educational research community (Fishman et al., 2004). If research-based curricular innovations are not sustainable, what hope is there that our investment in these materials will have a deep or lasting effect on education?

In this work, we were both surprised and pleased that so many of the teachers (53%) continued to use the SimCalc Mathworlds software and materials after the conclusion of the research study. The results from this study, together with emerging evidence from related work (e.g., Penuel et al., 2007), point to factors that should be attended to in further research on how best to support implementation of complex technology-supported interventions in mathematics and science. The finding that both coherence and value are important to decisions to continue with implementation should inform the design of educational interventions so that they that can be widely used to ensure that children have meaningful and deep interactions with important mathematics content.

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