Framespaces: Framing of Frameworks

Margaret Dickey-Kurdziolek
Education Elements, Inc.
999 Skyway Rd., Suite 325, San Carlos, CA 94070
meg@edelements.com

Deborah Tatar
Virginia Tech
2202 Kraft Dr., rm. 1123,
Blacksburg, VA 24060
tatar@vt.edu

Steve Harrison
Virginia Tech
2202 Kraft Dr., rm. 1121,
Blacksburg, VA 24060
srh@cs.vt.edu

ABSTRACT
Socio-cultural analysis [18], design practice [20], and philosophy, stretching back at least to Rogoff, Rittle, and Heidegger, all point out that we arrive at different pictures of difficult problems depending on the frames within which we examine them [16]. Yet after all this time, this truism remains difficult to approach. What can we make of these different perspectives? This paper explores how one system, for classroom mathematics education, looks different from experimental, ethnographic, and ethnomethodological frames during the investigation and different again as we try to put the frames into relationship with one another, that is, as we create a framespace. These different frames contend with one another in defining the meaning and the design brief going forward. We coin the term *framespace* to describe the constituent set of frames and the relationships between them that must be understood to describe the summative results of the project.

Author Keywords
Ethnomethodology, ethnography, educational technology, frameworks, framespaces

ACM Classification Keywords
J.4 Social and Behavioral Sciences: Sociology, H5.2. User Interfaces: Evaluation/methodology

General Terms
Design, Theory

INTRODUCTION
Socio-cultural analysis [18] points out that we come up with different pictures of system use depending on the frame within which we examine them. If, as Rittel claims [16], the most interesting design problems (the "wicked" ones) are characterized by a tight coupling between framing and strategy for solution, then the exact nature of the frame becomes very important. Schön also gives reason to believe that frames are consequential. He writes, "things are selected for attention and named in such a way as to fit the frame constructed for the situation" [20, p. 264]. When things are *not* selected and named to fit the frame, Schön warns that descriptions will flow more easily into prescription than a real critical awareness [20, p. 268].

The field of HCI is actively engaged in research and design to address wicked problems, such as education, the environment, health care, and politics. As such, in the HCI community there have been a number of discussions about the relationship between framing and systems design. However, the diversity of methodological and philosophical approaches can be overwhelming. In this paper, we present a construct called a "framespace", which draws attention to the need for explicit, critical discussion of the relationship between frames. Specifically we define framespaces as socio-technical conceptual spaces formed by critical reflection on the use, meaning, and values implicit in evaluative frames. Framespaces can help articulate the way different design, research, marketing, social good, and engineering frames together constitute the opportunity space within which artifacts and interpretations are created.

We illustrate the utility of framespaces by first examining how a particular system designed to address a particular "wicked" problem, classroom mathematics education, looks different as instantiated as different kinds of research problems: experimental, ethnographic and ethnomethodological. Each frame pulls aspects of the system, its use and its impact into view. Each suggests a range of values and forward trajectories. These values and forward trajectories are then articulated in terms of a framespace, which provides new avenues for discussing the meaning of "progress" in this endeavor and what lies within the scope of systems design.

DISCUSSIONS OF METHOD, MEANING, AND DESIGN
Throughout the history of HCI there have been many discussions on the relationships between method, meaning, and design. That is, discussions on the meaning of systems as they are viewed through different frames. Here we (1) review recent discussions on what methodologies and considerations lie "within systems design", and (2) the utility of a conceptual space for framing such discussions.

"Within Systems Design"
An incidental casualty of papers such as "Ethnography Considered Harmful" is the notion that our concern in un-

dertaking analysis for HCI is the nature of approaches to knowing about the world that are "within systems design" [6, p. 879]. By separating the world into ideas that are "within system design" and, by implication, into those that are not, we threaten to ignore the central question of framing, considering what a system consists of, how particular systems should be described, and what tasks designers should take on. Since its publication, there have been several responses to Crabtree et al.'s [6] delineation of the field and its consequences [3, 4, 14].

Recent literature has suggested that HCI queries should include not just new technological ideas, but personal and social responsibility, and deep questions about what a system is [3,4,14,24]. Bannon [2] points out that industry itself asks for new ideas for systems that interact with every part of life. Taking a less pragmatic stance, Tatar et al. [24] have suggested that design itself includes not only what is inside a system, but also what is excluded when that exclusion is done in a principled, disciplined way. This is echoed by Baumer & Silberman [3] who suggest that there may be complex multifaceted scenarios where technological solutions do not represent solutions at all. In these scenarios, the implication is to *not* design a technological system. This does not mean that investigation of such complex multifaceted scenarios falls outside the scope of systems design, rather that the question of "what and when to design" must include holistic (and realistic) explanations of what technology is and is not capable of accomplishing.

Our general view is that social science disciplines pursue different strategies for inquiry, and all appear to have some part or piece of the puzzle. So too do different approaches to empirical inquiry and sense-making that are more particular to HCI, such as activity theory, participatory design, think-aloud, GOMS, and value sensitive design [8]. However, any instantiation of a particular frame should be subject to critical inquiry and so too should the relationships between different frames. Framespaces is a way of thinking about the importance of such an endeavor.

Conceptual Spaces for Framing Thought

A "design space" helps us articulate the constraints within which we are searching for a solution [11]. The concept is not useful because it tells us the answer, but rather because it prompts us to use a range of perceptions, observations, and methodologies in the iterative exploration of possibilities. In fact, design spaces are not even necessarily static "things". Instead, they change as we move between abstract and representational expressions of the design space and potential design solutions, in a process shaped by the design methods we employ. Arguably, the most essential element in using the concept of a design space to produce "master work" is the justification it provides for critical reflection about our design methods, the very tools that change the design space [9]. Design space thinking justifies meta-level focus on the strengths and limitations they bring, the underlying philosophies and principals they embody, and facets of the design space they illuminate or fail to illuminate.

FRAMESPACES

Just as we use the mental model of the design space to help us articulate the constraints of our design, we need to build mental models of the meanings our systems could have to the eventual users and stakeholders and think about our empirical methods in relationship to those meanings. We call socio-technical meaning spaces, *framespaces*.

Frames as Value Spaces

Frames represent sets of values that are brought to the design and research process. In (Table 1) we have provided the heuristic descriptions of three frames that are familiar and frequently used in HCI research. These frames each proscribe approaches and kinds of findings that are "understood" – and valued - within their domains; they do not so much describe what to do as they describe what is important *and to whom*. While well-read HCI researchers can appreciate and interpret results across these boundaries, there is no way of establishing or recognizing that crossing. Furthermore, these boundaries and differing value-systems are often invisible to designers and policy-makers.

Table 1. Heuristic descriptions of three highly-recognizable frames

Frame & Summary
Experimental: Set of evaluation methodologies designed to provide verifiable, and most often statistical, proof of cause and effect.
Ethnographic: A branch of qualitative research methodologies, stemming from anthropology, which focuses on cultural phenomenon. The aim is to provide a holistic view of humans, artifacts, and the points they interact.
Ethnomethodological: Sociological study of human behavior with a particular focus on the rules, rituals, and methods they employ to complete work and interact with others and artifacts.

Expressions of Values within Frames: Triangulation

In theory, mixed method investigations benefit from the use of triangulation. With triangulation, methods are considered to be vertices that, in combination, can be used to indentify and describe a singular phenomenon. However, in practice, mixed methods often (1) premiate one frame over another and/or (2) provide supplementary dollops of material rather than integrated results [7]. Nowhere in the construct of triangulation itself is there a place or platform to articulate the values of the different frames and the premiation of some frames over others. We posit both that the boundaries between frames are established by the values implicit in the work and that those boundaries constitute a "frame". Furthermore, framespaces contributes to mixed methods research by providing the platform to describe the values and tension between and amongst frames.

Framespaces

A framespace articulates the meaning of the different frames in relationship to one another. The motivation behind the articulation of a framespace is to provide a vehicle for critical thought surrounding the values of different frames and their inherent meaning for a research project. To cartoon this a bit: frames hold claims of validity, and framespaces provide dialogue and critique between them. Table 1 shows a list of some familiar frames. Figure 1 shows a framespace.

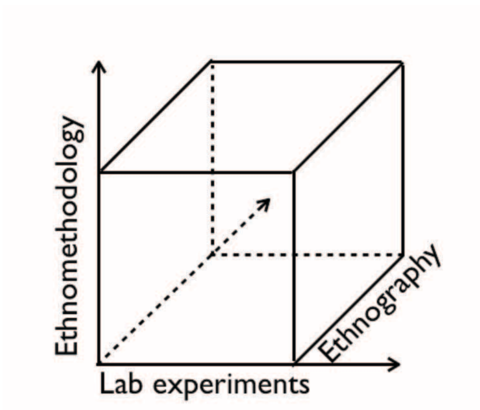

Figure 1. A framespace is like a design space, but about methods, their meaning and their associated values

SIMCALC, IN THE LAB AND CLASSROOM

This paper articulates the framespace surrounding a particular system examined with three different research frames that are familiar to HCI research: experimental, ethnographic, and ethnomethodological. Each frame pulls aspects of the system, its use and its impact into view and helps us to further define the framespace that may be used to put these frames into relationship with one another. The notion of a framespace allows us to assess different values present in the analysis of the socio-technical system and different forward trajectories for the project.

We first summarize the core technology and goals in the SimCalc MathWorlds® project. Then, we examine the experimental frame, of great interest to policy makers, administrators, funders and a certain class of scientists and education researchers in the United States. Next, we take a subset of issues brought into view using an ethnographic frame, which may be considered in different relationships to the experimental frame. Last, we view issues from an ethnomethodological frame and consider its relationship to the other two frames. Finally, we discuss new formulations of boundaries on design and research briefs.

SIMCALC MATHWORLDS®

SimCalc MathWorlds® is a technology for improving teaching and learning of the mathematics of change and variation. The technology embodies an approach that emphasizes giving students access to algebraic concepts graphically, dynamically and in relationship to simulations before before and along with algebraic functions. Students can play the simulation to watch the characters move in correspondence to the position graph they created, therefore experiencing the mathematical constructs of algebra and calculus as dynamic, motion based events.

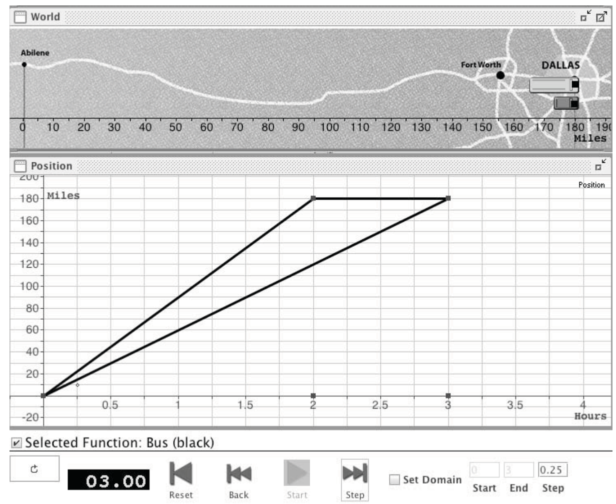

Figure 2. SimCalc MathWorlds® Screen-shot

Figure 2 is a screen-shot from a SimCalc MathWorlds activity used by the participants in Scaling-Up SimCalc study. In the image, the world shows two vehicles going on a road trip where the lower line (usually red) represents a van and the upper line (usually yellow) represents a bus. With this particular MathWorlds graph and simulation, the two vehicles start at position 0 at time 0. When the student presses "play" the bus and van move in correspondence with the graph, arriving at their final destination 180 miles away after 2 hours for the bus and 3 hours for the van. This kind of active engagement addresses deep sources of confusion in pre-algebra learners and leads to crucial learning.

THE EXPERIMENTAL FRAME FOR THIS STUDY

Low student performance in mathematics is a national concern in the United States [19]. Over the past 15 years, SimCalc MathWorlds has been evaluated in numerous small-scale design-research and quasi-experimental studies showing positive and promising results [10, 15, 21, 19, 25]. However, policy makers at the local, state and federal levels, school administrators and legislators wanted what they would call a systematic demonstration of value. So, too, did the funders (the National Science Foundation). They wanted "proof" that SimCalc worked in wide variety of classrooms. To do this, the researchers conducted a series of randomized, controlled experiments replicating and extending the hypothesis that a wide variety of students from a wide variety of settings could benefit from the use of SimCalc MathWorlds [19, 25].

Scaling-Up SimCalc Study Setting and Procedures

Since rate and proportionality is a central topic of 7th grade, 7th grade math classes and teachers were chosen to be participants in the first and most extensive study. The researchers implemented a delayed treatment design with two conditions to test their hypothesis. Teachers were assigned to condition randomly by school (that is, teachers in the same school were in the same condition). The experimental, or treatment group, was assigned to use SimCalc during year one, while the delayed treatment, or control group, was assigned to use SimCalc during year two. In year one, the control teachers were asked to teach their normal rate and proportionality unit. Students from both conditions were given a pre-test before their unit on rate and proportionality, as well as an identical post-test once the unit was completed. Full presentations of the experiments and their results are published in [19].

From an experimental point of view, study location has implications for how the study is conducted and for the generalizability of results. Diversity in teachers, students, and settings was necessary, but availability was also a consideration. The researchers chose to base the Scaling Up SimCalc study in Texas for three reasons:

1.) Access to teachers and students through the Charles A. Dana Center, at University of Texas Austin.
2.) Texas gathers comprehensive yearly data about schools and teachers that helped characterize the sample.
3.) State standards and testing were more stable in Texas than in other states.

The exact pedagogical goals of the experiment were influenced by this choice. 7th grade math classrooms in Texas typically focus on a formula-based approach to rate and proportionality (a/b = c/d) that has its foundations in elementary school mathematics, namely fractions. A typical problem requires the student to solve for a single unknown value when given three numbers in a proportional relationship. An alternative approach to rate and proportionality is to emphasize its relationship to algebra by formulating problems as function based (y=kx). A function-based approach requires students to find a multiplicative constant that maps a set of inputs to a set of outputs. To show that the intervention was successful in an experimental frame, students in the treatment condition needed to (1) learn standard mathematics to the same degree or better than their peers and (2) learn mathematics beyond what is normally taught [19, 25]. Pre and post-tests were developed to evaluate the students on standards for their grade level, as well as more advanced topics. To develop the pre and post-tests, the researchers used questions from the "TAKS", or Texas standards exam, to evaluate requirement number one. The TAKS (Texas Assessment of Knowledge and Skills) mathematics exam for 7th grade focuses on formula-based questions [1]. To test requirement number two, the researchers developed additional function-based questions on rate and proportionality.

Scaling-Up SimCalc Study Results

Year one of the study was completed with 95 teachers and 1621 students in 7th grade math classes throughout Texas. Students in the treatment condition had a higher mean difference score, or gain score, compared to their peers in the control condition (Figure 3, t(93)=9.1, p < .0001, e.s. 0.84, using a two-level hierarchical linear model with students nested within teachers). Students from the treatment group learned more, as measured by the test, than students in the control group [19]. Students in the treatment condition did especially well on the complex, or function-based, portion of the test as opposed to the simple, standards-focused, formula-oriented portion (t(93)=10, p < .0001, e.s. 1.22) [19].

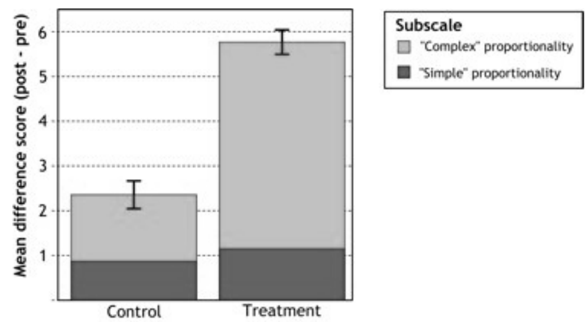

Figure 3. Results from year-one Scaling-Up SimCalc study

The Meaning of the Experimental Findings

From the Experimental Frame, the Scaling Up SimCalc study was a great success. Especially when combined with replicated experimental findings, it suggests a clear causal association between SimCalc and student mathematics learning. This is the kind of result that policy-makers and administrators like. It suggests that the designers of SimCalc play no more role, but may go back to developing other educational technologies. However, it does not explore what additional factors may be associated with success.

THE ETHNOGRAPHIC FRAME

While the year one learning gain results demonstrated the successful use of technology in class settings, we still had very little information on how the students and teachers interacted with the content, technology and curriculum.

The intention of the project was not to perform an ethnography, in the sense that we could not fully understand the circumstances of 95 teachers and over 1600 students. Furthermore, there were restrictions on what we were able to ask students. However, we were able to gather significant ethnographic resources, including student workbooks. Additionally, teachers kept a daily log of what they did, who was there, where the class was held, and how they evaluated it. Furthermore, at the end of the unit, we conducted semi-structured phone interviews, that lasted an average of 51 minutes. These interviews started with the questions of "what went well?" and "what went badly?" and touched on topics such as the class, the school, the region, the technology, the curricula, testing, and whatever else the teacher wanted to talk about, including prior training, beliefs about teaching, and career goals and choices.

The interviews were transcribed and coded using a Grounded Theory approach, describing issues in terms that the teachers had used [12]. These interviews uncovered a number of widespread patterns of concerns, attitudes, understandings and experiences that framed new issues for the designers. An interesting pattern was that the teachers did not categorize software installation problems as problems with the software. Over 27% of the treatment teachers mentioned having difficulty installing SimCalc in passing. However, no one mentioned this in their logs, no one used email or the free phone number that the experimenters had provided them with to report difficulties, no one complained about the instructions that had been given to them and it always came up incidentally in interviews, even when it involved lost class time, and led to significant instructional decisions. This put the question of "systems" design on the table for the SimCalc developers. Perhaps making SimCalc successful requires not only designing the application, but also taking on larger issues about the systems in which it needs to operate. That is a new design brief.

The interviews also revealed that the classes had a wider range of technical setups than were anticipated by the experimenters or discovered through other means. School principals and technology coordinators had agreed to make enough computers available during the unit so that each group of 2-3 children could have one each day. However, in some cases, the computers were only available for some classes and in others there were significantly fewer computers. Most teachers went to large computer labs. Others utilized traveling laptop labs. However, some simply used a small number of computers already present in their classroom [13]. Table 2 shows the technology set-ups during year one of the study. Teachers did not complain about the lack of computers. However, they did discuss how they thought about the arrangement of technology and how they thought it affected their students.

Table 2. Computer set-up for participants during year one of the Scaling-Up SimCalc study

Computer Set-Up	# of Teachers
Computer Lab	31
...with projected computer	*...6*
Computers on Wheels (COWs)	10
...with projected computer	*...4*
One Laptop with a Projector	5
Combination Lab & Classroom	1

While the interviews provided data on how different teachers thought and what they reported about implementing SimCalc, there was still no data on how learning opportunities for students varied.

ETHNOMETHODOLOGICAL FRAME

During Year 1 (Y1), we were able to make observations in 24 classes for a total of 44 classroom visits. In Y2, we wanted to understand the time course of instruction under different conditions. Observations were to be conducted over the entire length of the intervention. The first author of this paper conducted five weeks of field observations in four classrooms [12]. In addition to her first-hand observations, two video cameras and four microphones were set up each day. One of the cameras was positioned to capture the whole classroom; the other focused on a small group of students. This resulted in a total of 58 tapes or 87 hours of video data and roughly 150 pages of field notes and sketches. Also gathered were daily teacher interviews, digital pictures of the classroom and community, and student materials.

Table 3. Summary of initial logging scheme

Categories & Description
Class Start and End Times The moment when the teacher draws attention to the class as a whole, usually by giving a directive to the entire group aimed at calling them to order for the start of class or wrapping up the day's activities.
Technology Use Any action taken by a student or teacher towards classroom technology.
Discussion The inclusive vocal exchange of thoughts, ideas, instruction, and information at the classroom-wide level, between teacher and a student, or a student and another student.
Math Instruction When the teacher addresses the entire class with information about a specific math concept, such as features of a graph in the coordinate plane or how to algebraically represent a rate.
Individual/Small Group Work When the explicit and obvious classroom structure is constituted of students either working alone or in groups of two or more for a period of at least three minutes.
Workbook Use Any specific mention of or reference to the workbook by the teacher, whether directed to the entire class or a single student.
Other Materials Used Any time a teacher specifically mentions a non-computer item for student classroom use, such as a calculator, colored pencil, or straight-edge or ruler.

Subsequently, an expert middle school teacher with ethological experience, but no prior experience with SimCalc helped develop an initial low-inference logging scheme identifying coarse elements of classroom activity such as when the teacher made a move to begin instruction, when instruction actually began, when teachers gave certain kinds of directives, when technology use was initiated by students or teachers. Table 3 summarizes some of the 30 logging codes. He and an undergraduate research assistant under his direction used InqScribe (www.inqscribe.com/) to mark occurrences and changes on the videos. Since each class period had two videos, two observational documents were created for each. Teacher speech was clearly audible on both videos but was only logged on the video that showed the whole classroom. This initial scheme served as a platform from which to locate more fine-grained observations.

Participants
Four classrooms were targeted for in-depth observation including one teacher from each of the three main categories of computer use reported in the first year: Computer Lab, Mobile Laptop-Lab, and One Laptop with a Projector. Besides variation in technology set-up, other constraints included moderate homogeneity of first year gain scores, and that SimCalc instruction could not overlap temporally (since the observer could not be in two places at once). However, because two candidate teachers taught in the same school and both decided to teach during the same weeks, we were able to include a fourth teacher. The study-wide average gain score in Y2 was 5.23 (s.d. 3.89) on a 30-question test. All four observed classrooms scored slightly above average, but within one standard deviation of the study-wide mean.

The Computer Lab: One Computer Per Child

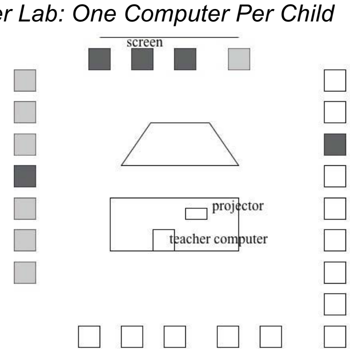

Figure 4. Teacher G's classroom (Squares represents a desk or computer; shaded squares represent student seats; dark shade for boys, light shade for girls)

Teacher G primarily utilized the school computer lab for the SimCalc unit. Her unit lasted eleven instructional days. Three were taught in Teacher G's usual classroom due to what she described as scheduling conflicts with the computer lab. Here she displayed the MathWorlds software on a TV located in the upper right corner of the classroom and led the classroom collectively through workbook activities and simulations. The remaining eight days were spent in a computer lab a short walk from her classroom. In the lab, each student had his/her own computer. Students ran the simulations on their own machine, while the teacher also ran and displayed the MathWorlds software on a projected computer in the center of the lab (Figure 4).

Mobile Laptop Carts
Teachers C and B were in the same school. Both used a traveling laptop lab. The school employed a rotating block schedule, so 45 min. classes alternated with 70 min. classes. The two teachers collaborated on their lesson plans, and chose to teach the SimCalc unit at the same time of year for seven instructional days. Students retrieved laptops from a cart located in the classroom and sat at their desks. Students were grouped into pairs, usually sharing a laptop. The pairing of students was also facilitated by the arrangement of desks in the classrooms (Figure 5 and Figure 7).

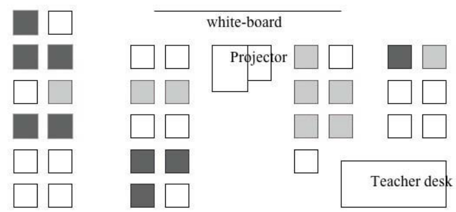

Figure 5. Teacher C's classroom

One laptop and a projector at front of the room
Teacher M spent four instructional days on the unit. She displayed MathWorlds software on a single laptop at the front of the class through a projector. She assigned a particular male student to be in charge of the laptop for the entire unit, and that student took directions from the teacher on when and how to run the simulations for the entire class. Teacher M also employed an overhead projector, on which she displayed transparency copies of the student workbooks. The class worked through each activity collectively. Teacher M would call students up to the overhead to fill in pieces of the workbook. Two students in Teacher M's classroom frequently moved their desks so they might see the projected simulation better (Figure 6).

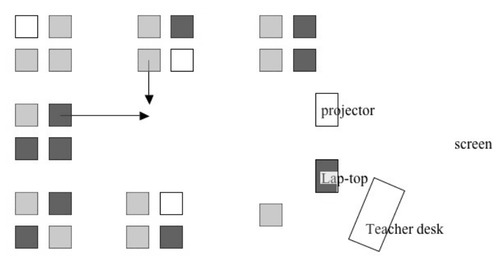

Figure 6. Teacher M's classroom

Analysis from the Ethnomethodological Perspective
The ethnomethodological frame brings into view particular *ethnomethods*, approaches to resource uses, physical arrangements, and classroom practices. We mention only two of the emergent themes from this analysis: resource sharing between students and managing attention to resources.

Resource Sharing and Control
When mobile laptop carts were used, student desks were pushed together into pairs, with the laptop positioned on the desk between the students. We detail an example of re-

source sharing between two girls in Teacher B's classroom (Figure 7) over the course of the intervention.

During one class period, the student on the left, Student A, initiated technology use 13 times and the student on the right, Student B, only 3. During this class, the orientation of the laptop shifted gradually towards Student A, until it ended up as shown in Figure 8. Student A did not orientate the laptop towards herself in one broad gesture; instead, she moved the laptop gradually over 27 minutes.

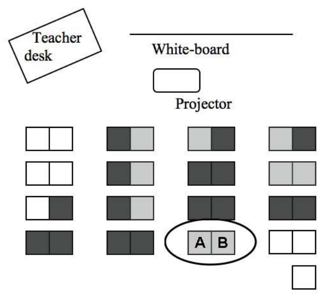

Figure 7. Teacher B's classroom, circling Students A and B

During this time, these students used other resources. The following transcript demonstrates the students' negotiations about colored pencils over a three-minute time span.

> [0:16:18.29] B has her workbook in front of her and is holding a green colored pencil. She is not writing anything, and her eye gaze is towards the front of the classroom. A is writing in her workbook with a brown pencil.
> [0:16:23.07] A puts down the brown pencil and reaches for the green pencil in B's hand. She takes the green pencil, and B picks up the brown pencil. Both begin writing in their workbooks.
> [0:16:40.22] B: "can I borrow your green one more time?"
> [0:16:43.15] A: "no"
> [0:16:47.03] B rests her head in her hand. She is not writing in her workbook, but is holding the brown pencil.
> [0:16:49.27] A puts the green pencil down on the desk and reaches for the brown pencil in B's hand. B picks up the green pencil.
> [0:16:52.12] B: "thank you"
> .... (Both write in workbooks)
> [0:17:15.10] B: "here is your stupid green back". B hands the green pencil to A.
> [0:17:20.14] A: "you are calling my green stupid."
> [0:17:21.25] B: "no I wasn't, I was saying cupid."
> [0:17:25.25] A: "I'm not stupid."
> [0:17:28.17] B lunges toward the colored pencils in A's hand. A moves the colored pencils out of reach.
> … (A writes in workbook; B sits staring straight ahead)
> [0:17:42.20] B lunges toward the colored pencils again. She takes the brown pencil.
> [0:17:45.24] B: "Ha Ha Ha. I got it."
> [0:17:47.15] A: "Not cool."
> ...(Students both write in workbook)
> [0:18:38.07] B: "can I borrow your green?"
> [0:18:39.07] A: "no"
> [0:18:41.21] B stands up and walks away.
> [0:19:11.00] B returns to her desk with another green pencil.
> [0:19:12.00] A reaches over and takes a ruler off B's desk.

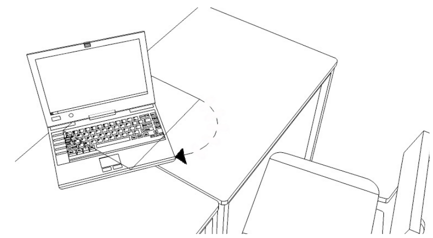

Figure 8. Pictorial representation of laptop movement between student pair in Teacher B's classroom

These interactions suggest that sharing resources in these circumstances engenders conflict for this pair. Making shared resources available for the other is not a routine behavior, at least for Student A, who repeatedly denies Student B access. We do not see reciprocity in their behavior. Student A takes a pencil from Student B's hand, but denies Student B access to her pencil, with no attempt at softening the language. Student B's response after obtaining access, "Ha ha ha. I got it", confirms that she does not accept A's authority over the matter. Additionally, we note a degree of overt personal involvement. When B calls A's pencil stupid, A first replies that the pencil is not stupid, and then she, A, is not stupid.

The turning of the computer suggests that the computer is part of on-going contention. Unlike the pencil, more cannot be obtained. Over the seven-day period of instruction, Student A, on the average, initiated laptop use 8 times in each class period, whereas Student B initiated use only 5 times. We see consistent inequity and on-going contention.

These students are having very different experiences from, for example, two boys observed in Teacher C's classroom who push their two laptops next to one another in order to be able to compare their work better---even though this causes both of them to have to write in their workbooks with difficulty because the left-handed one is on the left and the right-handed one on the right of their small desks.

Managing Attention to Resources

Attention is also a resource, and we observed a number of approaches to attention management. This was most apparent in non-peer interactions. Teacher G, who used the computer lab, frequently asked her students to turn around in their chairs and face her. On the average, she asked her students to not use the technology twice during a class, as illustrated in the following transcript:

> [0:04:07.06] Teacher: "where should your hands be right now?"

> [0:04:11.18] Multiple Students: "off the computers"
> [0:04:13.15] Teacher: "off the computers, okay. A rate compares quantities through division. See that in the workbook?"

In some sense, this interaction can seem inconsequential. Yet, later in the same class period, we notice evidence suggesting that computer use vs. non-use had status as something to be commented upon by students to one another:

> [0:24:03.22] A boy is sitting between two girls. He first looks to the girl on the left. Then looks to the girl on his right. The two girls are both using the mouse and focusing their gaze on the computer in front of them.
> [0:24:19.08] Boy says to the girl on his right: "you cheating"
> [0:24:21.19] Girl to the left: "what? Its fun. ::mumble:: the simulation. Look."
> [0:24:25.21] The boy looks to the girl on his left, then back to the girl on the right, then down to his workbook in front of him. He puts his head on the table.

Students come to understand the work of learning mathematics in settings that influence their notions of what constitutes appropriate technological and mathematical activity.

ARTICULATING THE FRAMESPACE

Each of the frames was instantiated in a particular way that requires justification in its own terms. Each frame, taken in its own terms, pulls to a set of values, decisions and the construction of meaning. However, many of these decisions were actually made with respect to an implicit framespace that ordered project priorities. We discuss some pulls that arose with respect to the central concerns raised by each frame: generalizability and validity, teacher instructional decisions, and resource sharing and control, and then reconsider the framespace.

The Relationship of Different Frames

-to Generalizability and Validity

For scientists, experiments represent a way of coming to know about the world in a valid, generalizable way. For consumers of science, they offer the promise of simple answers. For example, the U.S. Department of Education What Works Clearinghouse (http://ies.ed.gov/ncee/wwc/) is an attempt to give "thumbs up, thumbs down" answers to educational problems based on experimental studies. In HCI more generally, we also often just want to know what to implement. The promise of simple answers and the hope of fulfilling external desires for such answers can seem to isolate the experimental frame from other approaches. Here, the experimental frame is important for policy in schools in the United States of today and for students since first year algebra is a gate-keeper course for entry into quality four-year colleges.

The result is also situated in a cultural setting that assumes a set of conditions that may not be relevant all of the time. Ethnographic and ethnomethodological findings contribute to the generalizability and validity of the findings by suggesting issues that interact with mathematics learning. In particular, they may help avoid what Brown and Campione call *lethal mutations* to educational interventions that so detract from their success that they end up causing more harm than good [5].

At the same time, the experimental frame tells us that, on the average, there is important learning going on in these classrooms that may be detected over the period of the study and that this learning is increased compared to what it might otherwise be. Learning is not a directly observable phenomenon. We cannot say precisely what a particular person has learned at any given moment. Tests of complex learning have to be on a much larger scale than actual learning because we have no way to measure smaller increments to big ideas. The experimental results tell us that something that is happening in these classrooms is importantly positive.

- to Teacher Instructional Decision Making

The ethnographic frame draws our attention to the role of the teacher as a gatekeeper to student access and interpretation of the technology and curriculum. Teachers make instructional decisions when they decide how and in what way students have access to materials. Teacher willingness to use the technology is crucial for the success of the experimental enterprise. Teacher understanding of what it means to use the technology is also important. In particular, they treat flux in the availability of resources, including computer resources, as normal, that is, "not a problem". The decision about what computer facilities are necessary or desirable for instruction and who touches the software at different times are made in that context. Notably, these decisions were not primarily made on pedagogical grounds. For example, Y1 of the study, the teachers did not have prior experience teaching with SimCalc and no one knew whether it would be a success in experimental terms, yet teachers still made decisions about how and in what forms their students would have access to SimCalc.

- to Resource Sharing and Control

The ethnomethodological examination suggested that *resource sharing* and *control* may interact with conditions of success for SimCalc.

Observations about resources and control from the ethnomethodological frame interact explicitly with ethnographic findings. Teacher B, whose students struggled over the pencils and computer, puts a priority on grouping her students into pairs. By pairing students together, she hopes that they will, through dialog, use each other as a resource:

> "I like the fact that they were in pairs rather than individual …. even if they had their own laptops I would still push the desk together because even if they are doing their own thing I still want them talking back and forth and showing each other what they are doing …." – Teach. B

Either Teacher B has not seen conflict as shown on the video or does not evaluate it as a problem. However, to her, student resource sharing is important and consistent with the goals of middle-school mathematics.

Teacher C, from the same school, does not believe that student resource sharing is important or consistent with the goals of middle-school mathematics. She pairs students to handle a specific resource limitation: the number of laptops.

Likewise, the teachers see control issues quite differently and *can* see them quite differently because of their decisions about how to teach. Teacher M's use of only one laptop with a projector obviated detailed questions of student technology-use, but enabled her to claim:

> "They were in control of the laptop - of the program. I would read what the section was about and kind of like guide them and they were the ones that told me what to do" – Teach. M

Teacher G, whose students all had computers, characterizes the issue as one of sharing her students' attention with the computer:

> "So sharing their attention was something that I had to adjust to because I am like 'okay, everybody look at me, listen' because I realize that you can listen and kind of talk at the same time but as a teacher I want their attention. " – Teach. G

Teachers are essential to the endeavor and a crucial part of learning. In general, they know more about students than most people, especially about their own students. But they are also managing their own behavior in the moment and they do not see everything that happens in the classroom.

The Framespace

When we again consider the relationships between the three frames, we see the ethnomethodological can bear different relationships to ethnographic and experimental. In this project, the ethnomethodological frame was even more "controversial" than the ethnographic one because it was seen as not being sure to produce results of "significance." Indeed, when presented with findings of resource contention, some have commented "Well, that's just how kids/teachers are". Furthermore, neither the ideas that children and adults are capable of contention over resources, nor that they worry about control and attention, nor the higher-level interpretation of differences about control and resources as demonstrations of "classroom culture" are new. That is, it would be difficult to publish the findings from this frame as a dramatic contribution to our understanding of ethnomedothodological themes in situated action. However, far from merely showing that "that is the way kids are", the ethnomethodological frame here shows that this particular technology, used a certain way, offers the opportunity for appropriation for purposes and messages that neither designers, teachers, educators nor policy makers may desire.

The ethnomethodological frame uncovered themes in classroom behavior that interact with the goals of the larger project. This pushes us to consider designing a socio-technological response, which could take the shape of making actual design changes to the software, importing monitoring software, asking teachers to address sharing issues while using SimCalc, addressing possible pedagogical changes, or only working in schools with enough computers or with certain types of teachers and so forth. While the brute fact of resource contention is not novel, the way it plays out with this intervention is, thereby allowing us to consider design solutions.

CONCLUSION

The problem of designing technology for learning in American classrooms is undoubtedly a wicked problem. Wicked problems [16] change depending on how they are framed. By looking at technologies through an experimental frame, we are able assess the general or average success of the innovation. In the case of SimCalc MathWorlds, the researchers have shown, through experimental results, that when teachers and students use SimCalc, students learn more on a targeted test. Measuring the success of the innovation is important, especially for policy purposes. But, when we change the frame to that drawn from teacher beliefs and discussion, which we call here ethnographic, we see design challenges that did not appear previously, such as how to make certain kinds of systems work within the larger context of school computing. We also see assumptions and practices that seem to require further inquiry, such as the effects of different technology set-ups on learning. Our technology could accommodate those better, and we could advocate policies that alleviate the problems. When we look at these issues from an ethnomethodological frame on student and teacher behaviors, we see interactions between the work of doing mathematics learning, and behavior such as enacting and handling conflict and advancing and defining appropriate behaviors. The themes uncovered with the ethnomethodological frame push us to consider systems design in relation to the enacted classroom behavior.

In the future HCI will be called upon to spend more time investigating the role of technology in extremely complex socio-technical systems, such as those concerning the environment, health care, education, privacy, and diversity and equality. The question of how to frame of the investigation and the system will become more pressing. Just as we use the mental model of a design space to help us articulate the constraints of our design, we need to build mental models of possible framings and meanings the system might have to different constituents. Framespaces help us define the system, understand how the system will be conceptualized and incorporated into practice, and determine the realm of design considerations we are taking on.

Furthermore, the framespace is more than the space of socio-technical meanings from which we interpret our study. Framespaces provide the range of rhetorical and epistemological affordances to convincingly explain the value and the limitations of a technology. That is, framespaces build mental models of meanings the system might have for those who make decisions about it. For example, it is easy to say that sharing and attention behaviors are not part of mathematics, or technology design, and therefore not our concern. However, if they are on the critical path to increased system success we ignore them at risk of our higher goals. The purpose of HCI design and research is more than making systems "usable": critical reflection must encompass not just new technological ideas, but personal and social responsibility, and deep questions about what a system is.

ACKNOWLEDGMENTS

We would like to thank Dan Dunlap, Michelle McLeese, Ian Renga, and Jessica Watahovich, for their help in collecting and analyzing the interview and case-study data. We would also like to thank the members of the THIRD lab at Virginia Tech for their constructive advice.

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