Classroom resources and impact on learning

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ABSTRACT

In the past, educators and policy makers believed that by providing more resources they could directly improve student-learning outcomes. To their frustration, this turns out not to be entirely true. Resources may be necessary but they are not sufficient. Resources themselves are not self-enacting, that is, they do not make change inevitable. Differences in their effects depend on differences in their use. This is also true in the case of educational technologies. As developers of these technologies we need to understand how resources fit within the classroom environment as enacted and how they can be effectively used to increase student learning.

I report on four case studies conducted within the context of the Scaling-Up SimCalc study. In the study, “treatment” teachers were given a set of new resources to use: a combination of curriculum, educational software, and teacher professional development. “Delayed treatment” (control) teachers were asked to use their usual curriculum. Year-one study results demonstrated by randomized controlled testing the successful use of technology in class settings; however, there was little information on how the students and teachers actually interacted with the resources.

Case study classrooms were selected to examine the effects of variation of computational resource arrangements: one utilized a computer lab, two used mobile laptop carts, and one used a laptop connected to a projector. The first round coding and analysis shows that the observed classrooms varied not only in their classroom set-ups but also in how teachers and students interacted with the software, the workbooks, and with one another. The variety of resource interaction points to the robustness of the SimCalc project: students and teachers can interact with the SimCalc resources in a variety of ways and still achieve student-learning gains. However, through subsequent review and analysis of the observation data five themes emerged. These themes suggest commonalities in classrooms practices surrounding the use of resources. Two new theoretical constructs, “socio-physical resource richness” and “resource use withiness”, help describe (1) physical and social arrangements of resources and (2) how teachers and students manage resource use.
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Any opinions, findings, conclusions or recommendations expressed in this publication are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.
Dedication

I would like to dedicate this work to teachers, specifically the teachers that had a hand in my own education and the ones that welcomed me into their classrooms for this study.
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I would like to acknowledge my committee members, Roger Ehrich, Steve Harrison, Manuel Pérez-Quiñones, and Jeremy Roschelle, for their guidance. I would like to especially thank my adviser, Deborah Tatar, for her continued support and advice. I truly hope that I can continue to collaborate with my committee members in the future, as they have always pushed me to make the research better!

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Lastly, I would like to thank my case-study participants. I was warmly welcomed into each of the case study classrooms and I have fond memories of the students and teachers I observed. Ultimately, this experience has changed the way I view the world. I have found that the longer I spend observing classrooms and reviewing case study and interview data the more respect I have for teachers. Teachers are charged with the task of managing chaotic classroom environments while simultaneously facilitating student learning – a phenomenon neither assured nor easily witnessed. Furthermore, teachers often take on crucial roles in the larger community, such as counselor, coach, or simply “trusted adult” and confidant. Teachers are responsible for ensuring that future citizens will have the knowledge they need to participate and contribute to society. Teachers are charged with a nearly impossible but monumentally important job and they are wonderful people for taking it on.
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1 Overview

The word “resource” has many facets. In some uses of the word it means a source of supply, support or aid that can be readily drawn upon. At other times we use the word resource to refer to a capability or determination to persevere. In the context of classrooms, we see resources as physical demonstration aids, students’ contextual understandings, teacher subject expertise, and structured organization of materials, ideas, and activities. The points of contact at which students interact with these resources (noting that students themselves can be a resource) are where knowledge construction can occur.

In the past, educators and policy makers believed that by providing more resources, in the forms of money and materials, they could directly improve student-learning outcomes. To their frustration, this turns out not to be entirely true. Resources themselves are not self-enacting, that is, they do not make change inevitable. Differences in their effects depend on differences in their use (Cohen, Raudenbush, & Ball, 2002; Grubb, 2008). Classroom instruction can be described by the relationships and interactions between teachers, students, materials, and their environment (Figure 1). Instruction, therefore, is not something done by a teacher to their students, but rather a process in which knowledge is collectively and collaboratively built through and with classroom resources.

Figure 1. Instruction (from Cohen, Raudenbush, & Ball, 2002)

In the Scaling-Up SimCalc study, teachers started with whatever resources they, their students and their setting brought. Some teachers were then given a set of new resources to use, including curriculum, educational software, and teacher professional development. The immediate treatment teachers were asked to use the resources given to them in a 2-3 week replacement unit on rate and proportionality in 7th grade mathematics classrooms. Other teachers in the delayed treatment (control) were asked to use their usual curriculum. Results from the year-one experiment indicated that students in immediate treatment classrooms outperformed their peers
in delayed treatment classrooms. While these 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 our content, the technology and curriculum. In the second year of the study, we supplemented the main experiment with in-depth data gathering about the enactment of SimCalc in target classrooms.

Classrooms were targeted for in-depth observation based on the arrangement of computational resources the teachers reported using in the first year of the study. From the interviews we conducted in year one of our study, we found that some students had access to SimCalc MathWorlds® through personal laptops, others traveled to computer labs, and still more were only able to watch the software being used on an overhead projector (Kurdziolek, 2007). While the interviews provided data on what differences there were between different SimCalc classrooms there was still no data on how learning opportunities varied with these different resources.

1.1 Research questions

On one hand, classrooms are filled with resources and from a certain perspective more resources must lead to more opportunities and more opportunities must lead to more possibility of gain. On the other, students and teachers have limited attention and resources may entail distractions and opportunity costs. The questions in the current research are:

(1) How do different classrooms instantiate SimCalc in terms of enacted resources?
(2) What consequences does this have for student access to learning resources (of which computational technologies such as SimCalc MathWorlds are just one)?
(3) What are the possible effects on student learning and other outcomes?

I have set out to further explore the variation in implementations and resources SimCalc teachers used. Specifically I am interested in how varying degrees of technology availability influence teachers’ and students’ management and use of classroom resources and attendant learning. To address this concern, I conducted a series of in-depth case studies. I sought to observe teachers, and their students, with a variety of different technology settings. I selected the teachers I observed by examining their classroom set-ups. We can imagine that classroom events must proceed differently when instruction uses one laptop with a projector compared to when it takes place in a lab with computers for every 2-3 students. An on-going question in human-computer interaction is “precisely how do different ways of using technology effect the users?” In this case, by selecting case study participants based on their technology set-up and use I am able to ask, “how do different instantiated implementations of SimCalc affect students’ access to learning resources?”
2 Related work

The changes we create by introducing SimCalc technology and materials are, on the surface, a change to the material resources available in the classroom. However, if, as we did earlier, we conceptualize instruction as the interaction between the nodes of teachers, students, and resources (Cohen, Raudenbusch and Ball, 2002), then we must be interested not only in the state at each node, but in the relationships between the nodes and, furthermore, how our intervention might affect the nodes, the relationships and therefore the system as a whole. Current research casts light on some aspects of these states and relationships, and prior work on SimCalc guides our expectations and perspectives when approaching the new data. Five themes that emerge are (1) the conceptualization and effectiveness of the classroom space as a socio-physical environment, (2) the challenges that teachers face in developing quality instruction while handling changes in material resources and settings, (3) the relationship between students, their peers, and the content as well as teacher perceptions of the importance of these relationships, (4) the understanding of resources as systems of relationships and the impacts of these systems on student outcomes as well as resource adoption, and (5) what we learn and what we give up through studies that attempt to quantify general findings of resource use.

2.1 The arrangement of resources in the socio-physical classroom space

Typically, schools and classrooms are discussed and conceptualized as organizational units, that is, units used for organizational purposes such as describing and reporting student outcome measures and allocating resources and personnel. However, we can also focus on schools and classrooms as physical spaces, and describe them in terms of physical attributes and environmental factors. The physical characteristics of any space can influence the behavior of its users, and the characteristics of classroom spaces specifically can influence the behavior of students, teachers, and what we see as the educational program (Rivlin & Weinstein, 1984).

Although the idea is not uncontested (Montello, 1988), it is largely believed that students who are seated closer to significant targets of perception or interaction, such as the front of the room, perform better than students who are farther away (Becker et al., 1973). Furthermore, students’ choice of seating arrangement has been correlated with a number of factors that may interact with student learning. When students are allowed to choose their own seats, their position is highly related to their motivation, personality, and classroom participation (Weinstein, 1985). Indeed, students who choose to sit in frontal and central seats have been found to be more creative, assertive, aggressive, and competitive (Totusek & Staton-Spicer, 1982).

One study by Marx et al. (1999) looked at how the layout of physical classroom space influenced the relationships between students, their peers, the teacher, and the content being taught. Specifically, they compared how students behaved in a German elementary classroom arranged in traditional rows and columns and again in a semicircle formation. The children were randomly assigned to desks, and every two weeks the seat formation of the classroom would change as well as the seat assignment. This process was repeated for a total of eight weeks. Over the course of the study two researchers observed the classroom and recorded each question the students asked their teacher. The observers recorded a total of 158 questions over the 8-week period.
They found that the classroom seating formation affected the total number questions being asked and which students asked them. In particular, the students asked significantly more questions overall in the semicircle formation and there was no statistical difference between individual students. However, when the students were arranged into traditional rows and columns they asked less questions overall, and the questions that were asked came mainly from students sitting in the ‘T-zone’ or central and front areas. In other words, the physical arrangement of the space impacts classroom interactions and student engagement with their teacher (Marx et al., 1999).

Classrooms can not only be described as places for learning, but also as places for socialization and places for individual psychological development. Schools provide a mechanism for us to transmit the ideas and values of our society to children in preparation for their future adult roles. Also, classroom places contribute to the fostering of individualism, creativity, and self-esteem in young students. The physical design of the classroom space also interacts with these goals. In particular, the organization, aesthetic, and even affective quality of the classroom space has been shown to interact with students’ participation in classroom developmental activities, ability to stay on task, their attitude towards their teacher and peers, and engagement in exploratory and creative behavior (Rivlin and Weinsten, 1984).

In the case of SimCalc classrooms, the arrangement of computational resources may not only affect how the students gain access to the computer software, but also, as suggested by Marx et al. (1999), how they are orientated towards other important resources such as their peers and the teacher. For the current study, I chose to observe a selection of classrooms based on the set-up of computational resources. These set-ups not only affected how the students and teacher gained access to resources but also the physical set-up of the classroom, the distribution of actors in the space, and their orientation towards each other. For example, two of the teachers in the study who utilized mobile laptop carts arranged the student desks into pairs to better facilitate sharing of the laptop resource. We can imagine that the relationships formed between students sharing a laptop and arranged into pairs would be different than other student-to-student relationships formed in that classroom space. Furthermore, the nature of those relationships may interact with the students’ relationship to the SimCalc resources. When we think of classrooms as physical places designated as places for learning, socialization, and psychological development, the physical placement and orientation of students to important resources are critical factors.

2.2 Challenges inherent of instruction

After the first year of the Scaling-Up SimCalc study, researchers obtained statistically significant results indicating that students in the treatment condition had higher learning gains than their peers in control condition classrooms. This could be seen as a treatment (SimCalc) having a direct effect on outcome measures (student gains). This account is true but incomplete. Students’ relationship to much of the material and content SimCalc provided is filtered through teachers, in the sense that teachers received the SimCalc materials and were ultimately the ones who decided how and when the students accessed those resources. As Eugene Judson (2006, p. 583) put it, “[w]hen establishing any classroom innovation, it is the teacher who is the key determinant of implementation.” With respect to educational technologies, teacher beliefs in self-efficacy and the school context can affect their implementation and use of technology (Judson, 2006).
By some accounts, teachers are vital to the success of students. Yet the mechanics of what makes a good instructor are still largely a mystery. For over five decades researchers have been investigating the nature of instruction and which strategies meet with the best results (Cohen, Raudenbush, & Ball, 2002; Kounin & Sherman, 1979; Pianta et al., 2007; Pianta et al., 2008). State and local education boards use standardized student assessment and teacher credentials as measures to base the hiring and firing of faculty and the development of curriculum reform, yet research has shown that these factors do not necessarily correlate with successful teaching strategies.

In one qualitative, longitudinal study lead by Robert C. Pianta, researchers observed over 1000 elementary aged students as they progressed from first to fifth grade (from roughly six years of age to 11). In this study, they examined how factors such as teachers’ credentials, years of teaching experience, student activities, school settings, instructional quality, and emotional climate related to student learning gains in literacy and mathematics (Pianta et al., 2008). The researchers found that the quality of emotional and instructional support in classrooms contributed to the elimination of achievement gaps in first grade, predicted growth in children’s social functioning, and predicted reading and math achievement growth. However, the researchers found that classroom dynamics were not related to teachers’ degree status or years of experience. In many of the classrooms they observed the teachers met credentialing standards yet were mediocre in the quality of their instruction. Instead, quality of instruction was higher when teachers had fewer years of teaching experience, earned higher salaries, and reported more influence on school policy. The researchers concluded that, “if metrics and regulations for high-quality teaching continue to rely on teachers credentials or school attributes, then actual opportunities to learn may not be driven to improve” (Pianta et al., 2007).

What this research and other studies have shown is that quality instruction is vital to student learning, even if we haven’t been able to indentify the precise factors that would predict, influence, and define what quality instruction would look like in a given classroom. Good teachers have strategies, and as Jacob Kounin would say, “withitness” (Gladwell, 2008; p. 41). They know how to manage the instructional and emotional climates of their classrooms while simultaneously employing resources in ways such that they are aligned with their goals and students can use them. Exceptional instructors are able to mobilize a “complex collection of knowledge and practices, collective actions, and the conventional resources on which those actions and practices draw” (Cohen, Raudenbush, & Ball, 2002; p.86).

Kounin and Sherman (1979) investigated how the behaviors of 37 pre-school children and their teachers were affected by the environment and behavior settings within a school. Behavior settings are organizations of activity and resources, such as reading circles, arithmetic lessons, gym class, and music lessons, which appear to call for or afford (Gibson, 1977) certain behaviors. A behavior setting can be characterized by different dimensions including holding power (ability to hold students’ attention), amount of social interaction, amount of task involvement, and group glee (a phenomenon characterized by loud laughter from half or more of the group). The researchers found that the teachers’ task as behavior settings changed and shifted was to simultaneously deliver signals that supported appropriate behavior in the setting while also preventing inputs that would engender inappropriate behavior. The researchers concluded that the classroom was not a “homogenized glob” (Kounin & Sherman, 1979; p. 150), but rather
an environment in flux between different behavior settings. This indicated that “no one bundle of
teacher techniques or teacher attributes” can be prescribed manage the complexity of the
classroom, but that teachers should possess “bundles of techniques and must appropriately apply
these techniques differentially” (Kounin & Sherman, 1979; p. 150).

Throughout the course of the SimCalc study the researchers recognized that the teachers’ beliefs,
knowledge, experiences, and environment would be key factors that determined how and when
the SimCalc resources would be used. Therefore, in each year of the SimCalc study extensive
teacher interviews were conducted. From the year-one phone interviews, we found that the
teachers in our study were diverse in their teaching and professional backgrounds, had a variety
of kinds of involvement in their school and community, and reported varying degrees of collegial
support in their use of SimCalc. One important variation illuminated by the interviews was that
SimCalc teachers utilized technology in a wide variety of ways. This impacted how the
intervention was implemented (Kurdziolek, 2007). Cohen, Raudenbush, and Ball (2002, p. 86)
pointed out that “the impact of resources depends on their use”. Yet the studies I reported here
suggest that teacher credentials or years of experience cannot predict the successful use of
resources. To fully understand how teachers were able to successfully integrate SimCalc into
their classrooms, we must investigate the context of its use.

2.3 Students’ relationships to content, teachers, and each other

In classrooms where knowledge is treated as something fixed, that can be passed from instructor
to student, the teacher’s behavior may appear to be the primary activity. Students in these
classrooms frame their activities as the memorization of facts, algorithms and formulas (Cohen,
Raudenbush, & Ball, 2002). However, when teachers allow students to freely express their ideas
in their own terms, teachers can foster a classroom culture that interprets knowledge as
something to discover and reinvent. In these classrooms, students are able to frame their
classroom activities as the discovery of relationships and application of knowledge to real world
phenomena. Understanding the classroom means understanding the terms of engagement for
both parties.

As teachers are faced with the difficult challenge of taking the materials and resources provided
by SimCalc and making them useful to their students, so too are students faced with a difficult
challenge. Students often struggle in finding ways to communicate their understandings with
their teachers and peers. In a research study not unlike Scaling-Up SimCalc, Nancy Ares
identifies students’ cultural practices as an important learning resource that can be leveraged to
introduce students from marginalized groups to meaningful discourse in STEM fields (Ares,
2008). Her work focused on the use of Hub Net in secondary mathematics classrooms in inner
city New York. Hub Net technology is similar to SimCalc in that it focuses on shared
construction of mathematics learning and provides a way for students to link their current
understandings of the world to mathematical concepts. The students Ares observed were using
the “Gridlock” simulation, in which each student controls a stoplight in the City of Gridlock and
they are asked to prevent traffic build up. The student controls the stoplight through a graphing
calculator that is networked with a projected display of the city. Also displayed to the class are
graphs of the number of stopped cars, the average speed, and the average wait time at
intersections.
Ares found that students engaged in the Gridlock activity would first describe the events in informal language and were later pushed by the instructor to “translate” their expressions into more formal mathematical language. Students used their shared cultural backgrounds to create common ground and to collectively construct strategies for solving the Gridlock problem. For example, students in the Hub Net classroom drew on a variety of expressive modes, such as call and response, gesturing, and playful creation of words to communicate their experiences to one another and coordinate a successful traffic pattern.

Ares argues that the linkages between students’ existing cultural communicative practices and mathematical expressions are crucial for increasing student understanding and future participation in STEM fields. Furthermore, she asserts that students’ cultural practices can be used as a resource by teachers to link the students’ lived experience to math concepts. By recognizing students’ historically derived cultural practices instructors can encourage more students to participate and can strike a better balance between teacher and student talk (Ares, 2008).

While it is important to understand how students can communicate their understandings it would be invaluable to instructors to identify how their students are actually thinking about the material. Scherr and Hammer (2008) sought to understand how students in a first year university physics course framed their activities epistemologically. To do this, the researchers formulated a systematic protocol for finding evidence of student thought in video data. They grouped student behavior during small group work into four behavior clusters (with 95% agreement between raters). In the “blue” behavior cluster, students were primarily focused on their papers and briefly glanced at their peers. In the “green” behavior cluster, students would sit upright and make frequent eye contact with their group members. In the “red” cluster, students would interact with a teaching assistant, and in the “yellow” cluster students would giggle or smile with joking tones of voice.

The researchers found that while students demonstrated behaviors associated with the blue cluster, their main interaction was with the worksheet and had only occasional “check-ins” with their peers. In contrast, the green behavior cluster was characterized by original speech in loud animated voices between peers, indicating that the main interaction was the discussion. Throughout the course of the class, groups would frequently shift between the blue and green behavior clusters, and the researchers assert that these shifts indicated shifts in how the students were epistemologically framing the activity at hand. While the students were demonstrating “blue” behaviors, they were framing the activity as “doing the worksheet” and were engaged in more individualistic behaviors. While students were demonstrating “green” behaviors, they were framing the activity as “discussing the ideas” and were engaged in a collaborative creation and assessment of knowledge (Scherr & Hammer, 2008). In the case of the green behavior pattern, students were using each other as sounding boards for their ideas and collectively constructing an understanding of the physics concepts the activity intended to provoke.

Identifying how students’ prior experiences can be leveraged is not an easy task. “Even the strengths or disadvantages that students are said to bring to instruction are partly a matter of what their teachers can see and hear in students’ work and how skillfully they recognize and respond to them (Cohen, Raudenbush, & Ball, 2002; p. 92).” In the first study, Ares identified students’
prior experiences as a resource for teachers. Teachers could promote engagement and deeper learning by leveraging students’ cultural practices. The second study illustrated how students’ framing of activities could be identified and how the promotion of student interaction could promote desirable activity framing. In the case of the “green” behavior cluster, students were learning resources for each other in that their interaction and discussion enabled the creation of a collective understanding. When we apply this thinking to the SimCalc intervention we see that the relationships between students, their peers, and their instructor is vital in any attempt to improve classroom learning.

2.4 Models and conceptualization of classroom resources

The introduction of this report makes use of a classroom instruction model presented by Cohen, Raudenbush, and Ball (2003) (Figure 1). They use this model to present the idea of instruction and learning as a system of interactions: students interacting with other students, students interacting with their teacher, the teacher interacting with content, and students interacting with content. With the help of this model, we begin to conceptualize resources as more than just physical things, but as systems of objects, relationships, actors, and environments. While the instruction as interaction model (Cohen, Raudenbush, & Ball, 2002) is useful for understanding how learning is achieved through successful student-resource interactions, there are alternative models of classroom systems that can help us understand the relationships between available resources and their impacts on important factors such as student outcomes and resource adoption.

2.4.1 Taxonomy model of school resources and impact on student outcomes

In one such study by W. Norton Grubb (2008), he defined four categories of classroom resources and evaluated how the presence of these resources impacted factors such as student achievement and continuation of education after high school. Table 1 lists and summarizes the four categories of resources in Grubb’s taxonomy: simple, compound, complex, and abstract. Traditionally funding structures for education have focused on the increase of simple resources, resources that can be directly bought, in hopes that the increase of these resources would increase student gains. Grubb’s study sought to better understand and define the effects of simple resources on a variety of student outcomes, as well as the relationships between varying resources, school level factors, and their impact on students.

<table>
<thead>
<tr>
<th>Type of classroom resource</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Simple</td>
<td>Resources that are physical objects (eg. textbooks) or classroom factors (eg. teacher experience and expertise) that can be directly bought, adjusted, and measured</td>
</tr>
<tr>
<td>Compound</td>
<td>Two or more resources that are jointly necessary for success (eg. class size reduction and adequate teacher preparation)</td>
</tr>
<tr>
<td>Complex</td>
<td>Resources that are not easily bought, measured, or adjusted (eg. instructional approaches and teaching philosophies)</td>
</tr>
<tr>
<td>Abstract</td>
<td>Resources that are difficult to discern and measure, and often embedded in a web of relationships and practices within a given environment</td>
</tr>
</tbody>
</table>
Grubb identified and measured several simple, compound, complex, and abstract school resources and compared them to data from the National Educational Longitudinal Study collected in 1988 (NELS88). The NELS data was gathered on a national random sample of 8th graders in 1988, who were questioned again in 10th and 12th grades with follow-ups two and four years after high-school. With this data, Grubb was able to evaluate how different school and classroom resources affected immediate and long-term student achievement measures such as student test scores, student completion of high-school degree, and student enrollment in two and four-year colleges.

Grubb found that “simple” resources, such as textbooks, technology, increased teacher salary, teacher training, or lower pupil to teacher ratios may be necessary in some instances but not sufficient in and of themselves to influence student outcomes (Grubb, 2008; p. 107). For example, if a school decides to reduce class sizes, yet the teachers continue using the same strategies and practices that they would in a larger class then outcomes were not likely to change. They need the “compound” resource of reduced class size and modified instructional strategies. Indeed, many of the simple resources that are often stressed and discussed in education research and politics, such as pupil-teacher ratios, technology, and teacher education levels are not among the most powerful factors influencing student achievement. While many of the simple resources were necessary for student achievement, they were virtually never sufficient.

On the other hand, there were several “complex” and “abstract” resources that had significant impacts on student outcomes. When teachers felt in control of their classrooms in terms of subject material and instruction, identified as an abstract resource, students had higher test scores. Also, school climate, an abstract resource reported on by the students, was correlated positively with student test scores (p.125). Innovative math teaching was a particularly powerful complex resource, which affected both student achievement scores and their decision to pursue a 2 or 4-year college (p. 124). Many of the influential complex and abstract resources, such as student perception of school climate and teacher perception that their department encourages innovative teaching, were not influenced by monetary resources available but were rather socially constructed within the schools themselves.

In past research of student achievement in the United States (Caldas & Bankston, 1997), it has been found that family Socio-Economic Status is one of the strongest predictors of student success. Nonetheless, Grubb found that the explanatory power of family background proves to be smaller than school resources when complex and abstract resources were taken into account, and therefore, the theory that school effects are overwhelmed by family influences is incorrect (Grubb, 2008; p. 134). For educators and researchers in search of school reform, this is a hopeful finding. It suggests that efforts to improve school quality based on the increase of school-constructed complex and abstract resources could be beneficial. However such efforts require a deeper understanding of school dynamics and the way resources are employed and even created in the school and classroom contexts.
2.4.2 Ecosystem model of classroom resources and impact on resource adoption

Another way to conceptualize the complex relationships between teachers, students, and resources is as an ecosystem. Zhao & Frank (2003) presented an ecosystem model to explain factors influencing technology adoption and use in classrooms. All actors in the ecosystem interact with one another and those interactions are vital to any actor’s “survival” in the environment. However, in order for students to interact with meaningful content, they rely on their teacher to make the content accessible. Also, in order for any resource (technological or otherwise) to “survive” in the classroom climate, the teacher has to recognize its value and make it available for student use. With this metaphor, the teacher is the keystone species, computer uses are a “living” species, and the introduction of new resources, such as external educational innovations, can be seen as the “invasions of exotic species” (p. 811). Zhao & Frank argue that classroom ecosystems, like biological ecosystems, exist in a state of homeostasis – where the environment is in balance and each species has their role, or niche, in the hierarchy. Therefore, invading species, such as new educational technologies or educational interventions, are unlikely to survive or last unless they are compatible with the established teaching and learning environment (p. 813).

Zhao & Frank (2003) tested the usefulness of an ecosystem model of classrooms for the purpose of understanding educational technology adoption by conducting a study of technology use in 19 different elementary schools in four school districts in mid-western United States. They gathered survey data from all school staff, interviews with administrators and technology staff, and interviews and observations from four of the participating schools - one from each participating district. Once the data was collected, the researchers categorized possible influences of technology use into six categories: the ecosystem, the teacher’s niche in the ecosystem, teacher-ecosystem interaction, teacher-computer predisposition for compatibility, and opportunities for mutual adaptation.
They found that technologies found within classrooms, as opposed to computer labs or other locations in the school, were used more often. Zhao & Frank suggest this is because it costs the teacher considerably more energy to reserve and make use of technology outside their own classrooms than technologies within their classrooms. Also, teachers were the most frequent users of technology, while students were the least frequent users. Teachers often used technology for communicating with colleagues, parents, and administrators. Zhao & Frank argue that the communicative technologies were compatible with the current teaching environment, since they did not require teachers to change or alter their existing teaching practice. Furthermore, the communicative technologies were filling a “niche” in the environment, supporting teacher communication, which allowed those technologies to survive and prosper in the classroom ecosystem. In comparison, student use of technologies both required a reconfiguration of teacher practices and cost considerable energy on the part of the teacher. As such, those technologies were less likely to be used.

Zhao & Frank (2003) also found that teacher-niche in the school ecosystem, as well as their relationship to other “species” in the ecosystem influenced their use of technology. Teachers who perceived pressure from colleagues were more likely to use computers only for their own purposes and were especially resistant to using technology that would require a reconfiguration of their teaching practices. While teachers who received help from colleagues, and had opportunities to experiment with software, were more likely to use computers with their students than for their own purposes. Remarkably, the perceived relative advantage of student use of technology had no statistically significant effects on what technologies were used in classrooms. This illustrates that teacher rationale for using technology depends most directly on their own uses and needs, supporting their classification as keystone species in the environment. Zhao & Frank conclude that innovations cannot be implemented without a regard to the internal social structures of schools, especially teacher-level factors, and expect to survive in the classroom context. An “evolutionary rather than revolutionary” approach to change in school computer use is called for (p. 833).

2.4.3 Model of resource enactment for the current study

As presented in the previous sections, classroom resources can be framed in a number of ways, including taxonomies (Grubb, 2008) and complex eco-systems (Zhao & Frank, 2003). The conceptual framing of resources has impact on how studies are conducted and what phenomenon rise to the notice of researchers. In the current project, possible resources included students, teachers, physical artifacts, and the relationships between them; however, they were not described as resources until they were enacted as resources. That is, the actors, artifacts, and relationships in the classroom were not conceptualized as resources unless they were “doing being a resource”.
The critical element of this conceptualization of resource enactment is that resources can be any physical artifact, person, or relationships as long as they are used as resources. Practically speaking, this model of resources had impacts on what was recorded in the data gathering and analysis processes. Specifically, phenomenon noted in analysis were instances in which students and teachers arranged, modified, attended to, interpreted, or assigned value to an artifact, actor, or relationship. In short, resources were conceptualized as requiring enactment to truly be a resource, and the current project focused on those enactments.

Furthermore, this model of resource enactment is similar in many ways to the model of classroom instruction put forward by Cohen, Raudenbush, & Ball (2003) (described in the introduction of this document). In both models teachers and students are potential resources. Also, in both models, the classroom is conceptualized as a system of interactions and relationships. However, in contrast, the model of resource enactment I have presented here does not represent a model or method of how student learning is achieved. Rather, in this model, learning is a possible side effect of resource interactions and relationships. By modeling classroom resource enactments in this way we can describe different enactments of resources on their own, and it subsequently becomes possible to discuss different resource enactments in terms of a host of possible outcomes of which student learning is just one.

### 2.5 Technology as a classroom resource in the current climate

Since the invention of the home or desktop computer, the number of computers found and used within K-12 schools has increased enormously. In 1983, there was one computer for every 125 students in American K-12 schools, but by 1998 there was one computer for every six (Smerdon et al., 2000). It is a widely held, though not uncontroversial, belief that technology should be used and taught in K-12 education. Lumpe and Chambers (2001, p. 105) stated, “In order for our society to have computer-literate and functional citizens, we need to ensure that our children are obtaining the necessary modeling and training from the educators in their lives”. However, technology can be used in the classroom to not only teach children to be computer literate citizens, but also help students succeed beyond traditional chalk and blackboard methods.
The Scaling-Up SimCalc study provides a compelling example of a technology being used in a wide variety of classrooms with a high degree of success. It has been repeatedly demonstrated that students in classrooms using SimCalc resources perform significantly better than their peers in classrooms that do not use SimCalc resources (Roschelle et al., 2010; Tatar et al., 2008). Despite the success of technologies such as SimCalc MathWorlds, the recent “Effectiveness of Reading and Mathematics Software Products” (EETI) report released by the Department of Education seems to suggest that technology does not bring learning benefits to students. They reported that test scores were not significantly higher in mathematics and reading classrooms using selected technologies than classrooms not using technology (Dynarski, et al., 2007). This report has brought the use of educational technologies under attack in our high-accountability environment teachers find themselves in today.

The EETI study used a very insensitive measure. Both their control and treatment students did slightly better than random on the pretest and only gained an item or two after a whole year of instruction. This could have obscured real differences between the experimental and control conditions. Also, they used technology that was very different from SimCalc MathWorlds in that the technologies they chose were largely designed as tutorials, practice, and assessment. SimCalc MathWorlds, in contrast, focuses on classroom instruction and has been conceptualized as an integration of technology, curriculum, and teacher professional development.

While we can debate the validity of the EETI findings, the report did point out a factor that would influence any innovation’s success: Teachers control what technology is used and how long it is used in their classrooms. Use of the software products by the algebra students in the EETI treatment condition ranged from 5 to 30 hours in a school year. Technology use also varied between schools, and while the average number of hours treatment teachers used the technology was 46 hours, teachers in some schools used the software as long as 125 hours (Dynarski, et al., 2007, p. 66).

What causes one teacher to use a software product for only 46 hours in a year, while another teacher chooses to use the product for 125 hours or more? Perhaps the answers lie in the usability and adaptability of the software products. For one teacher, an educational technology may be a close fit for their teaching circumstances, while, for another, using the technology may present more of a challenge. As Cohen, Raudenbush, and Ball put it, “When conventional resources appear to affect learning accomplishments, it is because they were usable, because teachers and students knew how to use them effectively, and because environments enabled or did not impede use by these particular teachers and students” (Cohen, Raudenbush, & Ball, 2002, p. 102, emphasis added). In other words, the decision to use or not to use technology in the classroom, or the technology’s adoptability, is influenced by the technology’s relative advantage, complexity, and compatibility with the teacher’s existing beliefs, pedagogy, and environment (Rogers, 2003).

Once a teacher has committed to using technology in their classroom, a more pressing question appears: “how do they use it and do they use it effectively?” By examining teachers and students in authentic contexts, I will be able to provide a clearer picture of how resources are actually used and managed in a variety of different environments, and provide nuance to the findings in both the EETI report and Scaling-Up SimCalc study. My project will help shift the focus of
educational research away from “does technology enhance student learning” to “how and in what contexts can technology and resources be used with success.”


3 Context of the study – Scaling-Up SimCalc

For this study, I observed seventh grade math classrooms that were participants in the Scaling Up SimCalc study. Scaling up SimCalc is a large, randomized, controlled, multi-year investigation on middle school mathematics classes using SimCalc curriculum in conjunction with the SimCalc MathWorlds software. In this section I will outline a brief history of the MathWorlds software, its development and use in single classroom instances, and how this intellectual milieu has lead to the larger Scaling Up study.

3.1 Math pedagogy and technology

The math of change and variation (MCV) can be conceptualized as a strand of math learning that runs from kindergarten onwards, culminating for most children in today’s American schools in Algebra and continuing for some into Calculus and beyond. In 1994, James Kaput introduced a vision in which more sophisticated ideas about MCV could be taught and learned by using interactive technologies to allow students to link measurable events and experiences to formal mathematical representations. Grounding student understanding more firmly in motion and rate phenomena and focusing on the information captured in different representations, such as graphs and tables as well as algebraic expressions, would have, he claimed the twin benefits of teaching students more and teaching more students better. That is, the strongest students would have their understanding strengthened while the weakest students would have the gap reduced between their performance and the performance of the top students. Thus, this approach would democratize access to advanced mathematics.

To fully understand the math of change and variation, students must be able to establish a connection between real-world phenomena and their algebraic and graphical representations. A student’s ability to solve a math problem with real-world relevance relies on both the student’s linguistic understanding of the problem and consciousness of the underlying mathematical structure (Weber-Russell & LeBlanc, 2004). Also, students who lack previous experience with reflection are ill prepared to engage in the reflection that is required in solving more complex problems (von Glasersfeld, 1989). Students in this situation rely on the hasty application of rules without an understanding of the underlying relations to solve problems asked of them in math class. To expand a student’s ability to represent and manipulate mathematical concepts, their education must help them integrate procedural memorizations with conceptual understandings. The implication then for learning tools is to “facilitate children’s reflection on and exploration of whole structures and relationships in mathematically relevant contexts” (Weber-Russell & LeBlanc, 2004).

James Kaput and his colleagues sought to do just that when they were developing their own learning tool for MCV. The developers wanted to “begin with students’ intuitive experience with velocity” and “minimize computational complexity” so that a young and diverse population of students could conceptualize and understand the math of change and variation (Kaput, 1994). This resulted in the development of the MathWorlds software, which linked graphical representations to a “world” that could simulate real-world phenomena.
3.2 SimCalc MathWorlds™

The MathWorlds software supports dynamic graph creation and manipulation, in which graphical representations are tightly coupled with representations in a simulation “world”. Students can step through the motion graph, observe characters in the world, and examine tables with corresponding values. The graphs can be directly edited with the mouse, and the simulation world and tables will immediately reflect these edits. The image above (Figure 4) 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 red line represents a van and the yellow line represents a bus. With this particular SimCalc MathWorlds graph and simulation, the two vehicles would start at position 0 at time 0, and when the student presses play the bus and van will 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. There are several worlds the students can interact with, such as elevators in motion, ducks swimming across a pond, and clowns marching across the screen. The designers of SimCalc MathWorlds decided to implement five key innovations into the software: definition and direct manipulation of graphically editable functions, hot links between graphically editable functions and their derivatives or integrals, connections between representations and simulations, ability to import physical motion, and the use of physical/cybernetic devices (Hegedus, 2004).
The SimCalc MathWorlds approach presents Calculus ideas graphically rather than algebraically, which allows for the student to first understand the concepts pictorially and then move to numeric and algebraic functions later. 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. The developers wanted MathWorlds to be available on as many platforms as possible, so they decided to write the software as a Java application. MathWorlds is available on PCs and Macs, as well as hand held devices such as TI-83 calculators and Palms.

Figure 5. SimCalc/NetCalc running on a Palm (right) and a TI83 (left)

The creators of MathWorlds understood that “software re-use, integration, and activity authoring” were critical aspects that any educational program must embody if it has any hope of widespread success (Roschelle & Kaput, 1996). For this reason, they developed MathWorlds to have drag and drop capabilities, so that teachers and students could easily author and layout their own activities. They also made use of AppleScript and AppleGuide innovations on the MacOS platforms to integrate MathWorlds with Eudora email and MacMotion software, as well as allow teachers to author guides to suit their students.

3.3 SimCalc MathWorlds use in individual classrooms

One reason that students are hindered in their ability to master advanced math ideas is that a number of assumptions are made about math pedagogy. As Stroup (2004) puts it:

“We assume in our curricula and in our teaching that calculus is a subject to be studied well after the basics are mastered and only after a long series of prerequisite coursework has been taken. As a result, most of our students do not progress as far as calculus.” (p. 180)

Teachers are often told to address raised standards of learning without much support and no time to address advanced math concepts in an already crammed schedule. To combat this problem, Stroup suggests that advanced mathematics concepts can be introduced simultaneously with the basics when using a powerful simulation environment. He presents examples of 6th grade
students completing activities with the MathWorlds software. In all of the activities the students engage in calculus reasoning while developing their basic skills to complete the problem. Dr. Stroup concludes that, “using mathematical contexts closely associated with the study of calculus can be helpful, in very practical ways, in supporting our students’ developing understandings of what we often refer to as ‘basics.’” With the help of simulation software such as MathWorlds, math skills like subtraction, addition, multiplication, and division can be used and mastered while developing advanced mathematics reasoning.

Susan Nickerson, Cherie Nydam, and Janet Bowers from San Diego State University also studied the possible use of MathWorlds in classroom settings. They saw that the MathWorlds software focused on graphing first and moved progressively towards algebraic representations, and felt this was advantageous for students because it allowed them to connect the character’s motion with a graphical representation without first having to master algebraic equations. The researchers developed a curriculum for MathWorlds with three main themes: “1) graphing in the coordinate plane, 2) writing and evaluating algebraic expressions, and 3) understanding rate and change” (Nickerson et al. 2000, p. 2). They then observed the teacher and students while they worked with the curriculum and software. The researchers found that from the students’ point of view, “the use of technology enhanced the appeal of doing mathematics for a reason”, and from the teacher’s point of view, “the technology provided a context in which to ground abstract algebraic concepts”. They also found from a post-test administered to the students, that “students gained in understanding a number of pre-algebra concepts”. However, the authors recognized that there were some pragmatic difficulties in teaching with technology. The teacher had a difficult time attending to over 30 students in the computer lab setting, and it was “daunting” to create an entire instructional sequence (Nickerson et al., 2000).

The researchers at SRI had a vision that computers would be used frequently and integrally in K-12 classrooms. One reason that this vision has not yet been realized is that teachers often encounter difficulty in scheduling and using school computer labs (Tatar et al., 2003). However, there is one piece of technology that is frequently and easily used throughout American schools: the graphing calculator. Around 40 percent of high school math classes use graphing calculator, while only 11 percent use computers (Becker et al., 1999). Researchers at SRI sought to leverage the widespread use and acceptance of graphing calculators and handheld devices when they developed NetCalc, a version of SimCalc MathWorlds for Palms. NetCalc was co-developed with researchers, software developers, and two teachers. Developers did not want NetCalc to just be a scaled down version of SimCalc, but a separate tool that leveraged the small screen size and beaming capabilities of handhelds. Their efforts resulted in a design with four separate activities: Exciting Sack Race, Match My Graph, Slot Machine, and Aggregation. The researchers then evaluated the use of NetCalc in an advanced eighth grade math classroom located in the San Francisco Bay Area. The students performed significantly better on the post-test evaluation than on the pre-test. Furthermore, students using NetCalc outperformed high school students taking the AP calculus exam. This study demonstrated the potential impact of using the SimCalc innovation on small, affordable, and easily accessible handheld devices (Vahey et al. 2004).

Over the past decade, researchers have gathered evidence that supports the relative advantage of the SimCalc MathWorlds innovation. First, the researchers were able to show ordinary students learning more complex mathematics. They could also articulate the potential advantage of using
new representational capabilities to draw upon learner’s strengths and the need to change curriculum in schools to be more learnable. Shifting to controlled design experiments with carefully defined outcome measures, the team was able to show a causal relationship between SimCalc and enhanced student learning (Tatar et al., 2008). In these experiments they found that elementary, middle school, high school, and remedial college students could use SimCalc to understand key concepts in Calculus (Roschelle & Kaput, 1996). But are these studies evidence enough to prove the capability and viability of SimCalc? While the results are promising, the research team still needed to show that SimCalc could be used by a wide variety of teachers and students in a wide variety of settings.

3.4 The Scaling-Up SimCalc project

Currently in our country, every state administers some form of mandated statewide testing to their students. The teachers, principals, and district superintendents are expected to explain the results of these tests and seek ways to improve their students’ scores. Teachers also have a constrained amount of time to spend with their students, which pressures them to teach as quickly and effectively as possible. Educators do not have the time, resources, or support to try new educational innovations unless they can be sure that they will work. Educational researchers are charged with the task of creating and identifying curricula, pedagogy, and professional development activities that result in improvements across a broad range of settings. They must also demonstrate and explain the results of such advancements to teachers seeking new methods. This means that researchers must develop interventions that work not only in single classroom instances, but that work “at scale” (McDonald et al., 2006).

3.4.1 Study rationale

As illustrated in the Section 3.3, prior to the current study SimCalc MathWorlds had been evaluated in numerous small-scale studies showing positive and promising results. However, studies had yet to produce results that demonstrated SimCalc’s effectiveness at scale. In order to do this, the researchers needed to assess how their technology and curriculum would fare “in the wild”, where there is a large amount of variability in the teacher levels and school settings (Tatar et al. 2008). This led to the development of the Scaling Up SimCalc study, with the hypothesis that a wide variety of students from a wide variety of settings can benefit from the use of SimCalc MathWorlds.

3.4.2 Study design

The researchers chose a delayed treatment design with two conditions to test their hypothesis. 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. 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. The study design is illustrated in the diagram below (Table 2).

<table>
<thead>
<tr>
<th>Table 2. Experimental Design of Seventh Grade Study</th>
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<tbody>
<tr>
<td>Treatment</td>
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<tr>
<td>Treatment</td>
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<tr>
<td>Delayed Treatment (Control)</td>
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The researchers understood that whatever location they chose to base their study would have implications on how the study would be conducted, as well as the generalizability of their results. They wanted a place that would welcome involvement in a study such as theirs but was also diverse in teachers, students, and settings. The researchers chose to base the Scaling Up SimCalc study in Texas for three reasons:

1.) The SimCalc researchers partnered with The Charles A. Dana center, which is a leader in math and science teacher professional development in Texas, and has a good relationship with teachers and schools.
2.) The State of Texas gathers comprehensive yearly data about schools and teachers that helped characterize our sample.
3.) State standards and testing have been in place in Texas for longer than other states, and are more stable and mature.

Although the researchers wanted to choose a grade level that focused on rate and proportionality, like eighth grade algebra, they did not want to choose a “high-stakes” class. This is because teachers of high-stakes classes might feel anxious and less inclined to try a new, experimental teaching method. Since proportionality is a central topic of 7th grade, yet not considered high-stakes, 7th grade math classes and teachers were chosen to be participants in the study (Tatar et al., 2008).

At the time of this study, 7th grade math classrooms in Texas typically focussed on a formula-based approach to rate and proportionality ($a/b = c/d$). A formula-based approach requires the student to solve for a single unknown value when given three numbers in a proportional relationship. A more advanced approach to rate and proportionality is 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. The researchers felt that in order to show that the intervention was successful, they would need to show that students with the intervention (1) learned standard mathematics to the same degree or better than their peers and (2) learned mathematics beyond what is normally taught (Tatar et al., 2008). This required that the pre and post-tests would 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. To test requirement number two, the researchers developed additional function-based questions on rate and proportionality.

However, the researchers wanted to make sure that teachers in both the control and treatment conditions were exposed to the idea of teaching function-based proportionality. Therefore, all teachers attended a 16-hour TEXTEAMS workshop. TEXTEAMS is a teacher professional development workshop developed by the Dana Center in Texas. It was chosen for the study because it is “highly regarded and represents the state of the art in teacher professional development around the topic of rate and proportionality” (Tatar et al. 2008, p. 21). The following diagram summarizes the sequence of events during the Scaling-up SimCalc study that the teachers experienced while participating in the study (Figure 6).
3.4.3 Seventh grade year one 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 (p < .0001, e.s. 0.63), using a two-level hierarchical linear model with students nested within teachers. This indicates that students from the treatment group learned more than students in the control group (Tatar et al., 2008; Roschelle et al., 2010). Further more, students in the treatment condition did even better than students in the control condition on the complex, or function-based, portion of the test as opposed to the simple, standards-focused, formula-oriented portion (p < .0001, e.s. 0.89) (Tatar et al., 2008; Roschelle et al., 2010).

3.4.4 Seventh grade year two quasi-experimental study results

Year two of the study was completed with 67 teachers. That is, of the 95 teachers who participated in year one, 67 continued to participate in the study and used the SimCalc materials with their students during year two. Of the 67 teachers participating in year two of the study, 30 of them were in the delayed-treatment condition, that is, using SimCalc for the first time with their students. The data from 30 teachers and 1048 students (510 from year one, 538 from year two) assigned to the delayed-treatment condition were considered for a quasi-experimental study in which their year one gain scores were compared to their year two gain scores.
Table 3. Design of Year Two Quasi-experimental 7th Grade Study

<table>
<thead>
<tr>
<th></th>
<th>Year 1</th>
<th>Year 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Delayed Treatment (Control)</td>
<td>O₁</td>
<td>O₂</td>
</tr>
<tr>
<td></td>
<td>O₃</td>
<td>X</td>
</tr>
</tbody>
</table>

Overall, the year two seventh grade students benefitted from the use of SimCalc and had significant learning gains beyond the seventh grade students from the previous year (who did not have access to SimCalc) \((p < .0001, \text{ e.s. 0.50})\). Furthermore, the students from year two did even better on the complex portion of the test compared to their counterparts from the previous year \((p < .0001, \text{ e.s. 0.69})\) (Roschelle et al., 2010).

Figure 8. Gain-score by treatment year for 7th grade, year 2, quasi-experimental study (pre- and post-test contained 30 items)

3.4.5 Eighth grade study results

In addition to the seventh grade study, a one-year, randomized, and controlled evaluation of SimCalc was conducted with 56 teachers and 825 students in eighth grade classrooms. Similarly to the seventh grade study, the eighth grade treatment teachers were given a SimCalc “package” to use with their students, which consisted of teacher professional development, curriculum, and SimCalc MathWorlds® software. The eighth grade study also took place in Texas, however, schools chosen for the seventh grade study were not chosen for the eighth grade study so we could ensure that the teachers and students had not seen or used SimCalc before.

Table 4. Experimental Design of the Eighth Grade Study

<table>
<thead>
<tr>
<th>Treatment</th>
<th>O₁</th>
<th>X</th>
<th>O₂</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>O₁</td>
<td>X</td>
<td>O₂</td>
</tr>
</tbody>
</table>

The curriculum or unit for the study was called “Designing Cell Phone Games,” and focused on mathematics more relevant for eighth grade students such as linear functions and average rate. The unit was designed to promote learning gains on mathematics that is typically found in eighth grade curriculum in Texas, as well as more conceptually difficult mathematics. In particular, categorizing functions as linear or nonlinear, or proportional or non-proportional, and translating one linear function from one representation to another are skills typically found in eighth grade.
Also, skills beyond what is usually taught in eighth grade were presented, such as interpreting two or more functions that may be linear or segments of piecewise functions, and finding average rates for piecewise functions. Like the seventh grade study, the eighth grade pre- and post-test was designed to evaluate student learning on both eighth grade standards (“simple”) as well as more advanced mathematics (“complex”).

Furthermore, the teacher professional development for the eighth grade study followed a “train-the-trainer” model. In this study, the train-the-trainer model meant that SimCalc researchers trained a small group of teacher-trainers on how to make use of the SimCalc materials, and these trainers then taught regional training workshops to the teachers who ultimately used the SimCalc unit with their students. The benefit of a train-the-trainer model is that it requires even less intervention on the part of researchers, and therefore is more sustainable. However, the train-the-trainers model adds another degree of separation between the SimCalc researchers and the teachers who ultimately use the SimCalc materials. This could potentially reduce the teachers’ understanding of the overarching SimCalc goals and may increase the variation in teachers’ use of SimCalc resources. (Dunn (2009) conducted case-studies investigating the robustness of the train-the-trainers model for the SimCalc eighth grade study, which is reported on in Section 3.6.)

There was a significant overall affect suggesting that students in treatment classrooms performed better than their peers in control classrooms (p < .0001, e.s. 0.56), and similar to the results found in the seventh grade study, students in treatment classrooms did even better than their peers in control classrooms on the more complex portion of the test (p < .0001, e.s. 0.81).

![Figure 9. Gain-score by experimental condition for 8th grade, year 3 study (pre- and post-test contained 36 items)](image)

**Figure 9.** Gain-score by experimental condition for 8th grade, year 3 study (pre- and post-test contained 36 items)

### 3.5 Study of SimCalc adoption and spread

The goals of the Scaling-Up SimCalc project has been to both (1) facilitate deep student learning of the mathematics of rate and change, and (2) develop resources such that a wide variety of teachers and students can adopt and benefit from SimCalc. Early in the development of SimCalc, the researchers recognized that student learning was best facilitated by “compound” resources, or the combination of multiple resources. A favorite slogan of James J. Kaput, the SimCalc program founder, was “new technology without new curriculum is not worth the silicon it’s
written in” (Roschelle et al., 2010, p. 9). In the Scaling-Up SimCalc study, the technological resource, SimCalc MathWorlds was paired with student workbooks, teacher curriculum guides, and teacher professional development. Experimental results suggest that students who engaged with the SimCalc resources learned significantly more than their peers who did not have the benefit of SimCalc. However, the experimental results on their own offer no insight into whether the SimCalc resources were compatible with the classroom ecosystems they were introduced into or had hope of widespread adoption. That is, there were still lingering questions about SimCalc’s potential to be used by teachers in the study after the study and researcher support had concluded and whether teachers would be inclined to share the SimCalc resources with peers and colleagues.

One year after the Scaling-Up SimCalc study concluded, the 7th and 8th grade teachers were asked to participate in a study of SimCalc adoption and diffusion (Hegedus et al., 2009). All of the teachers who participated in the Scaling-Up SimCalc study were asked to complete a survey to determine whether they were still using the SimCalc materials (measure of adoption or “stick”) and/or shared the materials with colleagues (measure of diffusion or “spread”). The survey consisted of 15-items focusing on the teachers’ familiarity with SimCalc, their previous use of SimCalc, the important components of SimCalc teachers would share with a colleague, what they would tell their colleagues and administrators about SimCalc, and any problems or barriers they experienced in implementing SimCalc.

A total of 189 teachers participated in the Scaling-Up SimCalc studies, and of those, 79 teachers participated in the “stick and spread” study. 48% of the respondents were still using SimCalc materials (described as “stickers”) and 67% had shared the materials with colleagues and friends (described as “spreaders”). Teachers who continued to use SimCalc materials (“stickers”) reported that the SimCalc materials cohered well with their instructional goals and the accountability requirements of their school. Teachers who shared the SimCalc materials with colleagues (“spreaders”) also felt that SimCalc met their instructional and accountability goals, but also reported a high-degree of collaboration amongst colleagues in their school and felt comfortable seeking help from colleagues and administrators at their school. The results indicate that teachers’ perceived coherence of the new educational resources, as well as school climate factors such as their collaboration with colleagues can predict the stick and spread of education interventions. In terms of potential adoption of educational resources such as SimCalc, it suggests that not only does the resources have to fit a niche within the classroom ecosystem, but also teachers may require a system of collegial support at their school. This requires that the new resources be coherent with school-wide goals as well.

3.6 Details of classroom level impacts

In addition to the gathered experimental data and phone interview data, a number of case studies were conducted throughout the course of the 3-year Scaling-Up SimCalc project. Researchers from Virginia Tech and the University of Texas conducted a series of two-class period case-studies in 24 classrooms during the first year of the study to investigate how different classrooms implemented a particular lesson called “On the Road”. Pierson (2008) conducted case-studies in thirteen, seventh grade mathematics classrooms during the second year of the study to investigate how the intellectual work required of students in the classroom and the teacher’s responsiveness to student dialog affected student outcomes. During year three of the Scaling-Up SimCalc study,
Dunn (2009) conducted case-studies with the eighth grade train-the-trainers workshop, three regional SimCalc workshops led by teachers who were the participants in the train-the-trainers workshop, and eight eighth grade classrooms to better understand how the train-the-trainers model implemented during the third year eighth grade study affected the teaching strategies used. Each of these studies have investigated a particular facet of contextual use of SimCalc resources and have illuminated ways that individual classroom dynamics impact the overall SimCalc effect.

Dunn’s (2009) dissertation work looked at how the train-the-trainers model used in the eighth grade study affected the SimCalc training teachers received and ultimately their implementation of SimCalc curriculum. One of the over-arching goals of the Scaling-Up SimCalc study is to determine the robustness of SimCalc resource use. Robustness for an educational intervention such as SimCalc would imply that students in classrooms using SimCalc would still achieve learning gains despite variations in the specifics of teacher instruction and other classroom level factors. While Dunn (2009) found that some of her case study teachers did not always teach SimCalc lessons in the way they were designed or intended, the students in those classrooms still achieved positive learning gains. In particular, Dunn (2009) found that her case-study teachers’ instruction varied on a number of different factors, including their emphasis and use of the workbook and technology resources, the nature and structure of small-group and whole-class work, the type and tone of whole-class and teacher-student discussion, and even the ways in which teachers presented particular mathematical concepts such as graph interpretation. Despite these variations in instruction, all of the classrooms in the case studies demonstrated some (though wide-ranging) student learning gains. (The average classroom learning gains in Dunn’s case studies ranged from 7.8 to 2.2 items, or 22% to 6%.) Dunn concludes that the robustness of the SimCalc resources depend on teachers 1) presenting the main ideas of the lesson accurately, and 2) giving students a reasonable amount of autonomy with the materials. While theses key aspects of instruction ensure that some essential student learning takes place in SimCalc classrooms, the full potential of what students can learn with SimCalc materials seems to be influenced by the nuances of student-teacher-resource interactions.

In Pierson’s (2008) dissertation work she analyzed the transcripts from thirteen, 7th grade classroom case studies and coded teacher’s follow-up responses to students’ questions for degree of responsiveness and required intellectual work. Responsiveness in this study denotes the degree to which the teacher attempts to understand what a student is thinking after the student has asked a question. Responsiveness is demonstrated through the way the teacher builds, questions, clarifies, takes up, or probes what the student has said. Intellectual work denotes the degree to which cognitive work is requested from the students with a given turn of teacher talk. Pierson found positive correlations between the levels of teacher responsiveness and levels of intellectual work with student learning as measured by the SimCalc post-test and gain scores. Furthermore, in classroom communities where the teacher demonstrated higher levels of responsive discourse moves, the predictive value of the students’ pre-test on post-test scores was diminished. Similarly, in classrooms where a high level of intellectual work was presented to students the predictive power of student pre-test scores was diminished. This means that a high degree of teacher responsiveness and intellectual work could potentially “level the playing field” for some students. Based on these findings, Pierson (2008) concludes that classroom discourse
normative modes of interaction can influence student learning in tremendous and often unnoticed ways.

While the larger social context and organizational structure of the classroom may impact the moment-to-moment interactions had by students and teachers, it is these micro or local level interactions that make up student learning activity and ultimately constitute the macro or global structure of the classroom. To borrow an example from Pierson (2008), while the classroom activities of show-and-tell, lab experiments, or even following a SimCalc lesson may be used to largely describe the classroom processes, they do not describe how the activity is realized by particular students in particular classrooms (with particular resource set-ups) under the guidance of a particular teacher (Pierson, 2008; p. 14). As Pierson (2008) and Dunn (2009) have argued in their work, and I similarly assert, it is the moment-to-moment decisions and interactions that are the life of the classroom and through which learning is potentially achieved. While Pierson (2008) focused on teacher talk and teacher response to students and Dunn (2009) focused on the robustness of teacher-training models on teacher action, the focus of the current project has been on student access, use and construction of classroom resources.
4 Methods, data, and analysis

The frameworks we use to view the world influence the type and scope of phenomena we record and notice as analysts. They provide form for the meanings we make from observations, and structure the conclusions and documents we produce. Regardless of the framework chosen, the methods we employ shape the process and outcomes of our inquiry.

Researchers pursuing quantitative explanations of phenomena shape their experiments and explanations in such a way that all factors that could affect the outcome measures are controlled for. Other researchers with similar expertise and equipment should be able to replicate the experiment and duplicate study results. Ideal quantitative studies take place in sterile lab environments, in which all qualities are explicitly known and documented. Arguments about the validity are based in this process of experimental control and study replication.

However, even in quantitative analysis the conclusions are qualified by the connections observed between the laboratory-tested and real-world phenomena. These qualifications are usually written up as “broader implications” of the study at hand. Broader implications allow the laboratory scientist to theorize about the robustness or sensitivity of the experimental phenomena outside the laboratory. As scientists, it is crucial to qualify our observations with respect to our own knowledge and experiences so we can both (1) better describe the phenomena under study and (2) theorize on its importance and impact to the world outside of sterile and controlled conditions. The hallmark of qualitative research is to bring such qualifications to light to better understand human actions, decisions, and social processes.

Unlike in quantitative frameworks, the data-in-hand in qualitative research cannot be reproduced. A qualitative researcher must do his/her best to capture the phenomena and its importance as it unfolds. But the reproducible elements lie in researcher’s act of interpretation that locates the meaning of particular behaviors in context. A qualitative researcher endeavors to capture the moods and important scenes they experienced much the same way a novelist tries to convey their meaning through thick, rich descriptions. Thick description is more than just description of behavior, but also description of the meanings events have for those who experience them (Eisner, 1997; Geertz, 1973).

In qualitative research, the means for creating knowledge is an “enlightened eye” that crafts text so that “what the observer has experienced can be shared with those who were not there” (Eisner, 1997; p. 30). Of course, this means that the final result of a qualitative analysis is the interpretations of the particular observer. Indeed, two researchers observing the same phenomena may produce similar yet different reports because they are viewing the phenomena through their own lenses, shaped by their individual and unique experiences and expertise. This makes the most fundamental tool used in qualitative inquiry the researcher him or herself. As Elliot Eisner put it, “The self is an instrument that engages the situation and makes sense of it” (Eisner, 1997, p.34). We insert ourselves into the analysis and interpret the significance of the phenomena. This is not considered to be a fault or drawback of qualitative research; on the contrary, it is embraced and regarded as one of its cornerstones. “We display our signatures. Our signature makes it clear that a person, not a machine, was behind the words.” (Eisner, 1997; p.36).
A common purpose in many qualitative research traditions is to explicate the ways people come to understand, account for, take action, and otherwise manage their situations (Miles & Huberman, 1994). For example, Grounded Theory is concerned with the discovery of regularities in banal, or normal, occurrences of everyday life (Glaser & Strauss, 1967). These regularities are described as themes, and are used to categorize social elements, such as the logic and implicit or explicit rules that govern behavior (Goulding, 1999). Other qualitative methods of inquiry, such as phenomenology, still focus on how people come to understand, account for, take action and otherwise manage their situations, but resist condensing observations into codes or themes. Discourse analysis emphasizes the meaning of spoken language, and collaborative action research facilitates and encourages behavior changes on the part of participants.

Grounded Theory espouses a need for a “holistic” overview of the context under study. This is achieved by (1) immersion into the context under study, (2) attention to and description of behaviors and speech acts (coding), (3) the naming of emergent patterns of behaviors (themes), and (4) theorizing the meaning of these patterns of action and interaction. In practice, this usually entails an iterative process of coding and reviewing collected data, such as video, transcripts, and field notes.

In classrooms, a well-chosen example or case study can help students gain insight. Similarly, ethnographic case studies can illuminate the context-dependent phenomena in question and raise analytic understanding of them to the “expert” or “connoisseur” level (Flyvbjerg, 2006, p.222; Eisner, 1997, p.17). In studies of educational settings, such as Scaling Up SimCalc, case studies provide a “nuanced view of reality” in which we can begin to understand the context of classrooms and student achievement beyond the simple rule-based theories provided by quantitative measures (Flyvbjerg, 2006, p. 223). As a rule, students in classrooms using SimCalc resources have higher learning gains as measured by the administered pre- and post-test than their peers in classrooms that did not have access to SimCalc resources (see Sections 3.4.3, 3.4.4, and 3.4.5). From teacher interviews, as well as teacher daily logs, we see indications that the reality of student engagement with SimCalc materials may vary from classroom to classroom, depending on classroom set-ups, availability of resources, teacher instruction, and potentially other factors not yet recorded in our study. If we truly hope to understand how SimCalc can be used with a wide variety of teachers and students in a wide variety of settings (that is, raise our understanding of SimCalc use to the “connoisseur” level), then we must investigate the context-dependent nature of instruction in actual classroom settings.

I conducted four case studies with a stratified sample of teachers and their students participating the Scaling-Up SimCalc study. I analyzed the data from a grounded-theory perspective. The case-study participants were chosen for the varying ways in which SimCalc MathWorlds was made available to the students: direct access, in which each student had access to their own computer; shared access, in which each students shared the computer with a peer; and indirect access, in which students observed SimCalc being used on an overhead projector. By investigating the ways these specific collections of people arranged and interacted with SimCalc resources, we hope to gain a better, more nuanced understanding of how student learning is achieved. In the following Sections I will review how the observation participants were selected, describe my protocols for data gathering, and explain the data analysis.
4.1 Case study participants

All participants in the Scaling-Up SimCalc study were located in Texas. Also, since proportionality is a central topic in math for 7th graders, all of the participants were teachers of seventh-grade math (Tatar et al., 2008; Roschelle et al., 2010). From the teachers’ daily logs, and the post-unit phone interviews, we found that the teachers using SimCalc had different technology set-ups for their classrooms. While most teachers went to computer labs, the rest utilized traveling labs (COWs) or simply used a small number of computers always present in their classroom (Kurdziolek, 2007). The following table shows the technology set-ups the teachers reported in the Y1 phone interviews:

<table>
<thead>
<tr>
<th>Computer Set-Up</th>
<th># of Teachers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Computer Lab</td>
<td>31</td>
</tr>
<tr>
<td>...with projected computer</td>
<td>...6</td>
</tr>
<tr>
<td>Computers on Wheels (COWs)</td>
<td>10</td>
</tr>
<tr>
<td>...with projected computer</td>
<td>...4</td>
</tr>
<tr>
<td>One Laptop with a Projector</td>
<td>5</td>
</tr>
<tr>
<td>Combination of Computer Lab &amp; Classroom Computer</td>
<td>1</td>
</tr>
</tbody>
</table>

Four classrooms were targeted for in-depth observation based primarily on the arrangement of computational resources the teachers reported using in the first year of the study. I choose one teacher from each of the three main categories: Computer Lab, Computers on Wheels, and One Laptop with a Projector. Besides the variation in technology set-up, I wanted the other factors to be fairly homogenous across the group. So I chose teachers who were considered to be in Mid-SES (Socio-Economic Status) school systems (as measured by the percentage of students in the school who qualified for free or reduced price lunch) and had average gain, rather than extreme, scores from the first year of teaching with SimCalc. An additional concern was that I was only available for observations during the Fall 2006 semester, and I could only observe in one location at a time, so the teachers’ units could not overlap with one another. However, because one of the candidate teachers taught in the same school as another and both decided to teach during the same weeks, I was able to include a fourth teacher using COWs.

Before I went to Texas, I needed to contact the chosen teachers and explain that I wanted to observe them. For the first phone call, I developed a short speech that could explain my research to the teachers:

“Hello, my name is Meg Kurdziolek, and I am a researcher with the Scaling-Up SimCalc study. You may have spoken to me before when you did a post-unit interview last year. This year, my colleagues and I are going to classrooms throughout Texas to see how SimCalc MathWorlds is working out. We are interested in how you and your students use the technology, and what problems and advantages the technology presents to a real classroom. In short, we want to see how MathWorlds does in the ’real world’.”
From this point, I would ask them about when they planned on teaching the unit, how long they expected it to take, what if any instruction or curriculum changes they planned to make to the SimCalc unit, if their technology set-up would be the same as what they reported in their year one interviews, and other details about their school. After the first phone call I called the teacher every couple of weeks, asked them how their school year was going, and confirmed the details they had told me before.

4.1.1 Selected participants

![Map of Texas education districts and participant locations.](image)

In the map of Texas above (Figure 10) the gray areas represent regions, or education districts, where participants in the larger SimCalc study were located. The starred areas represent cities the teachers I chose to observe were located.

<table>
<thead>
<tr>
<th>Pseudonym</th>
<th>Computer Set-Up</th>
<th>Region</th>
<th>City</th>
<th>Days Observed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Teacher M</td>
<td>One Laptop connected to Projector</td>
<td>18</td>
<td>Kermit, TX</td>
<td>4</td>
</tr>
<tr>
<td>Teacher C</td>
<td>COWs + projected computer</td>
<td>13</td>
<td>Round Rock, TX</td>
<td>7</td>
</tr>
<tr>
<td>Teacher B</td>
<td>COWs + projected computer</td>
<td>13</td>
<td>Round Rock, TX</td>
<td>7</td>
</tr>
<tr>
<td>Teacher G</td>
<td>Computer Lab</td>
<td>13</td>
<td>Milano, TX</td>
<td>11</td>
</tr>
</tbody>
</table>

4.1.1.1 Teachers C & B

Two teachers (Teacher C and Teacher B), within the same school, used COWs. They collaborated frequently on lesson plans, and chose to teach the SimCalc unit at the same time and for the same length of time, seven instructional days. Their school was located in Round Rock, a mostly white suburban city in the Austin Unified School District. The school had 1044 students in the 6th, 7th and 8th grades. Teacher C was a white woman with 12 years mathematics teaching experience. Her class consisted of 23 students and included five special needs students who were sometimes accompanied by special needs instructors. Teacher B was a white woman that
had been teaching mathematics for 20 years after a prior career in sales. Her class consisted of 25 students, including 3 who were designated English language learners.

4.1.1.2 Teacher G
This teacher utilized the school computer lab for the SimCalc unit (Teacher G). She was located in Milano, TX, a rural, largely Caucasian setting about 45 miles outside Austin. Milano, TX has a small population of 414 people (City-Data, 2007). The school had 78 students in grades 6, 7 and 8. The teacher, a white woman with 18 years experience teaching mathematics, was the only mathematics teacher in the school and reported that she had a lot of autonomy. The class observed had 14 students. The unit lasted for eleven instructional days. Four out of the eleven days were taught from Teacher G’s usual classroom, largely due to scheduling conflicts with the computer lab.

4.1.1.3 Teacher M
Teacher M utilized one computer attached to a projector for the SimCalc unit. She was located in Kermit, TX, which is about 60 miles away from Midland, TX in the western part of the state. Kermit has a small but ethnically diverse population of 5,136 people and nearby Midland has a population of 103,880 people (City-Data, 2007). The school had a population of 267 students in 6th, 7th and 8th grade. Teacher M’s target class had 25 students. Teacher M is a white woman who had 11 years of teaching experience at the time of my observations. I was able to observed Teacher M and her students for four instructional days.

4.1.2 Participant year 2 gain scores
For each class, an average gain score was calculated by averaging the difference scores for each student. Difference scores were calculated by subtracting the student’s pre-test score from his/her post-test score. There were a total of 30 questions on the pre- and post-test, and the study-wide average gain score during year two of the Scaling-Up SimCalc study was 5.23 with a standard deviation of 3.87. Table 7 shows that each of the classrooms I observed scored above the study-wide average gain score for the year, but within one standard deviation of it.

<table>
<thead>
<tr>
<th>Pseudonym</th>
<th>Computer Set-Up</th>
<th>Y2 Gain</th>
</tr>
</thead>
<tbody>
<tr>
<td>Teacher M</td>
<td>One Laptop connected to Projector</td>
<td>7.05</td>
</tr>
<tr>
<td>Teacher C</td>
<td>COWs + projected computer</td>
<td>6.55</td>
</tr>
<tr>
<td>Teacher B</td>
<td>COWs + projected computer</td>
<td>5.76</td>
</tr>
<tr>
<td>Teacher G</td>
<td>Computer Lab</td>
<td>8</td>
</tr>
<tr>
<td><strong>Study-wide</strong></td>
<td></td>
<td><strong>5.23 ± 3.87</strong></td>
</tr>
</tbody>
</table>

I did not know the case study classroom’s year-two post-test and gain-score results until nearly two years of the observations were concluded.

4.2 Observation procedures
I introduced myself on the first day of observations in each classroom with the following speech:

“Hello everyone, my name is Meg, and I am here to visit with you for a few weeks. I’m really interested in the math you are learning at school, as well as how you use
computers and software. So I will be filming you just to see how you use MathWorlds and your workbooks.”

After I introduced myself, I located a group of students to film, and set up my cameras. One camera was positioned to take in a wide angle of the whole class including the teacher. My rubric for positioning the other camera involved finding a place that did not involve stretching the power cord across a walkway, identifying a student group rather than a single student, and trying to get a group from the middle of the room. In three cases, this resulted in a focus on student groups that were in the middle at one side of a classroom. In the fourth, I had to film from the back. After that, I set up my cameras in the same place every day and filmed the same groups of students.

I used two cameras, a sound mixer, and two microphones to capture video and audio data. One camera was positioned on a small group of students and was connected through the sound mixer to the two microphones I would place on the students’ desks. The other camera was positioned near the front of the classroom and focused on the whole class of students. From the first camera I was able to record detailed conversations and collaborations between selected students, and from the second I was able to record the teacher’s movements and whole class interactions.

I also kept daily field notes and periodically collected student workbooks to photocopy. At the beginning of every day I documented the date, time, period, lay out of the classroom, the number of students present, where the students were sitting, who the students were grouped with, and any outstanding points about the day (ex. homecoming, football game, shortened class schedule, fire drill, etc.). Throughout the course of the class I documented student-to-student dialog, teacher-to-student dialog, references to the workbook or software activities, and any additional diagrams or resources the teacher may have provided in the moment.

After each class, I briefly interviewed the teachers. Interviews ranged from 2 to 30 minutes, depending on the teacher’s availability. Each of these interviews was recorded on camera and/or documented in my field notes. Every day I asked the teachers:

- *How did this class go?*
- *Did it go as you expected it to?*
- *What do you think went really well?*
- *What do you think could have gone better?*
- *Were you able to complete everything you had planned to do?*
- *What are your plans for tomorrow’s class?*

As the teachers answered these questions, I asked follow-up questions to better understand the issues and experiences they had. For example, often the teachers would say “They really got it” and I would ask “What did they really understand?” I also used these interviews as a chance to get to know the teacher, let the teacher get to know me, and build rapport with them.

### 4.3 Data gathered

I spent a total of five weeks in Texas conducting observations with the four teachers. I took with me two video cameras, four microphones, a sound mixer, MP3 recorder, DVD burner, digital camera, laptop, and a sketchpad. I positioned one of the cameras to capture the whole classroom
at a wide angle, and focused the other camera 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. I also conducted
daily interviews with the teachers, took digital pictures of the classroom and community, and
made copies of student materials.

Another graduate student collected very similar data, choosing teachers not with a focus on
resource use, but on variation in classroom socio-economic status. She gathered 49 days of
classroom observation in four classrooms. In the future, these data may be used to supplement or
extend any analyses undertaken by the current project.

4.4 Analysis

Once the observations were completed and the raw data was brought back to Virginia Tech, the
data went through a staged organization and analysis procedure typical to ethnographic and
particularly Grounded Theory analyses (Goulding, 1999). For this particular study, the data went
through four stages of description and analysis. A summary of this process is presented in Table
8.

<table>
<thead>
<tr>
<th>Table 8. Summary of Data Analysis Process</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stage 1: Collection and Organization of Data</td>
</tr>
<tr>
<td>All physical copies of data sources of data were imported to digital media files and named based on a file naming scheme that captured the following information: SimCalc Teacher ID #, date data was gathered, raw data type, and any additional information surrounding the data source such as camera angle and location. The data was then reviewed and used to create case descriptions.</td>
</tr>
</tbody>
</table>

4.4.1 Initial coding and analysis

After returning from our observations in Texas, a video-analysis team was assembled, including
undergraduate research assistants from Psychology and Mr. Ian Renga, an expert middle school
teacher with ethological coding experience, but no prior experience with SimCalc. Mr. Renga, Dr. Tatar, Michelle McCleese (another member of the case-study team) and I co-developed an initial coding scheme. This scheme was designed to be non-inferential, identifying recurring categories of student and teacher behaviors visible on the video. It was developed to describe broad elements of context and activity, such as focus on homework. Table 9 shows some of the initial codes and their operational definitions. The full list can be found in Appendix A.

Table 9. Summary of initial coding scheme

<table>
<thead>
<tr>
<th>Codes</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class Start and End Times</td>
<td>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 (i.e. “Let’s take a seat.”). This may also include statements that serve as more passive directions intended to call students to order, such as, “Wow! It’s loud in here!”</td>
</tr>
<tr>
<td>Technology Use Initiated by Student or Teacher</td>
<td>Any action taken by a student or teacher towards computers and/or overhead projectors (but not calculators).</td>
</tr>
<tr>
<td>Technology Use Start and End for Students and Teacher</td>
<td>The moment that students begin to use or stop using classroom technology, usually in the form of a computer. “Start” is usually characterized by students logging in to a computer or opening a laptop, and “End” is usually characterized by students logging off or closing the laptop.</td>
</tr>
<tr>
<td>Technology Delay Start and End</td>
<td>The moment class instruction or activity is halted due to a technology related issue, such as computers lacking the SimCalc program, or an error or glitch in the technology that renders it inoperable. Technology delays can also be concurrently coded as “Instruction Interrupted” if they, indeed, interrupt ongoing instruction.</td>
</tr>
<tr>
<td>Discussion involving the Whole Class, a Teacher to Student, or Student to Student</td>
<td>The inclusive vocal exchange of thoughts, ideas, instruction, and information by two or more individuals at the classroom-wide level (Whole Class), between the teacher to an individual or small group of students (Teacher-Student), or students to their peers (Student-Student).</td>
</tr>
<tr>
<td>Math Instruction</td>
<td>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. Discussion Teacher-Student is used to denote instruction addressed to one or more students, usually involving teacher proximity to the group.</td>
</tr>
<tr>
<td>Instruction Interrupts</td>
<td>The moment when on-going classroom activity is halted to address a non-related or technical issue, such as when somebody enters the classroom and solicits the teacher’s attention while she is conducting a class-wide discussion. Often students begin focusing on non-class related matters.</td>
</tr>
</tbody>
</table>
| Individual/Small Group Work                | When explicit classroom structure is constituted of students either working alone or in groups of two or more for a period of at least...
Since each class session had two videos taken from different perspectives, a member of the video analysis team watched both videos and created two documents. Each document contained time stamped codes with brief annotations describing details specific to the requirements of the particular code, such as which student was responsible for a noted behavior. The video analysis team used InqScribe™ analysis software so the codes would be tied directly to timestamps in the video (http://www.inqscribe.com/).

4.4.2 Secondary coding and analysis
Throughout the process of reviewing the gathered data and actively coding for classroom behaviors, the researchers on the project would meet regularly to reflect on the student and teacher interactions with resources, to note behaviors common across classrooms and to discuss unusual behaviors, only witnessed in a few classrooms. The initial coding scheme resulted in descriptive statistics about classroom sessions. For instance, we could begin to describe the frequency with which teachers engaged in whole-class and teacher-student discussions, and the number of times students visible to the camera initiated technology and/or workbook use. The initial coding allowed us to pick out from the large data set behaviors that were in some sense comparable, for example, times when students were using workbooks.

The classrooms had been chosen because of the differential use of computer resources across classrooms observed in the first year of the study. Therefore, the secondary coding scheme focused on identifying resources and change in access to resources during instruction. The initial scheme allowed us to look at the data in context in a way that helped identify the range of resources to be considered. It prompted questions such as why, during a particular exercise, one student initiated workbook use 19 times, while her partner initiated it only 8? (Student workbook use data from Teacher B observation day 113006.)

We developed the secondary coding scheme using the framework of the initial coding scheme. For example, one set of behaviors that stood out in the context of “students using workbooks” was the process of workbook sharing, that is, students looking at other students’ workbooks and showing their own workbooks or handing over workbooks. Noticing this behavior caused us to develop the codes “Student Resource Show/Give” and “Student Resource Look/Take” in the secondary coding scheme. These interactions seemed prevalent, purposeful and possibly relevant to the task of learning mathematics.

The secondary coding scheme consists of 13 individual codes nested within 3 categories, which are summarized in Table 10, with a focus on giving, taking and changing resources of different kinds. The dissertation author conducted secondary round coding.
Table 10. Summary of Secondary Coding Scheme

<table>
<thead>
<tr>
<th>Codes</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physical Resources Properties, Arrangement, and Rearrangements</td>
<td>Physical resource arrangements and properties in the classroom spaces, pertaining to whole-classroom arrangements or small-group arrangements. Also, whenever resources were rearranged or reallocated (e.g. whole class moves desks to work in student groups, student moves desk closer to front, in a small group of students one student shifts a laptop closer to them, etc.). The codes “Student Rearrangement” and “Teacher Rearrangement” were used to demarcate when a student or the teacher was responsible for the resource movement.</td>
</tr>
<tr>
<td>Teacher Action and Arrangement</td>
<td>Teacher actions and arrangement towards physical resources and their students. For example, when the teacher moved from the front of the class to standing and walking among student desks, the actions were recorded with the “Teacher at Front of Class” or “Teacher Among Students” codes. Also, when teachers discussed the use of physical resources, such as mentioning that the students shouldn’t or should be using the technological resource, the action was recorded with the “Teacher Discussing Resource use” code.</td>
</tr>
<tr>
<td>Student Action and Arrangement</td>
<td>Student actions and arrangement towards physical resources and their interactions with other students and their teacher. For example, when a student showed or gave their student workbook to another student the action was recorded with the “Student Resource Show/Give” or “Student Resource Look/Take” codes. Also, when students discussed the use of physical resources with their teacher and other students, such as asking the teacher if it was okay to use a calculator, the action was recorded with the “Student Discuss Resource Use” code.</td>
</tr>
</tbody>
</table>

Secondary coding was conducted using InQscribe™ analysis software. The observations were recorded as time stamped codes with brief annotations describing details specific to the requirements of the particular code, such as which students were interacting with one another and/or what physical resources were involved in the interaction. A complete list of the secondary coding scheme codes and their operational definitions can be found in Appendix B.

4.4.3 Organization of behaviors into themes

The initial coding scheme allowed us to broadly describe a range of classroom behaviors and identify the moments that teachers and students interacted with each other and resources. With these moments identified and cataloged, we were able to focus our attention on the nature of how and when students gained access to learning resources. The secondary coding scheme was developed to capture the moments students accessed learning resources, the movement of resources across the classroom spaces, and any teacher and student discussion of learning resources. The behaviors coded with the secondary coding scheme were then examined and organized into commonly observed behavior patterns or themes.
To facilitate the process of organizing observed behaviors into themes, I used a card sorting method (Turner, 1981). That is, unique behaviors noted in the secondary coding scheme were written onto index cards. The cards were then organized into categories based on similarities of behavior. For instance, multiple teachers in the study made statements such as “look down at the graph drawn in your workbook” or “look up at the overhead, please”. Since these behaviors similarly involve the teacher telling students to focus their attention on a particular resource, these behaviors/cards were grouped together. Once all of the cards had been sorted, the piles were examined individually and given a name. The naming was done to reflect the nature of commonalities between the sorted behaviors. For example, the grouping of behaviors reflecting teachers’ direction of student attention was organized into a theme named “Attention Management”.

### 4.5 Chapter summary

In this chapter, I have described the study’s research methodology, participant selection, data gathering, and data analysis processes. A qualitative, grounded theory methodology was used to uncover and describe regularities of student, teacher, and resource interactions in a select number of classrooms. The teachers and students observed were all participating in the Scaling-Up SimCalc study, and the classrooms were selected based on their set-up of computational resources. In particular, one classroom made use of a school computer lab, one classroom made use of a single laptop connected to a projector, and two classrooms made use of mobile-laptop carts. A variety of data sources were used and gathered, such as observation video, observer field notes, digital pictures, and observer sketches. These data then went through a four-stage analysis process that resulted in the organization of student and teacher actions into behavior themes. These themes allow use to point out and discuss important aspects of teacher/student/resource interactions in the classroom settings, and theorize on the resource arrangement impacts on outcomes such as student learning. The study sought to make contributions to the fields of computer science, in which developers of educational technology seek a better understanding of the classroom contexts as it applies to technology design, and to the learning sciences, in which researchers hope to better understand the reality of resource use in classrooms and the impact on student learning.
5 Results from observations and initial coding

The goals of the current project were to (R1) describe in detail how the set of observed classrooms varied in their use of SimCalc, (R2) demonstrate the potential consequences of these implementations on student access to learning resources, and (R3) theorize on the effects to student learning and other outcomes with regards to resource access, allocation, and use. By systematically observing classrooms, reviewing video and field note data, and coding data for patterns of student, teacher and resource interactions, I was able to develop thick descriptions of classroom behavior from which we are able to generate theories about student, teacher, and resource interactions. In this chapter I will describe my observations and experiences from spending extensive time in each of the classrooms, and report on the descriptive classroom statistics calculated using the initial coding scheme.

5.1 Case descriptions – How observed teachers implemented SimCalc

The four case-study classrooms were selected based on their variation of on a particular factor: technological set-up and the corresponding inferred use of SimCalc resources. However, the four classrooms also varied on a number of other factors, including the community setting, school setting and size, physical classroom size and arrangement, number and type of students, responsibilities and experience of the teachers, and other potential variations due to the specific faculties of the school, classroom, teacher, and students. Throughout the course of conducting the observations and subsequently reviewing the gathered data, I would record the variety of factors that impacted how classroom events proceeded. The following sections provide a narrative description of each of the classrooms with a focus on singular factors that characterized how those particular classrooms proceeded.

5.1.1 Computer lab case - Teacher G

Figure 11. Teacher G's computer lab
At the time of observation, Teacher G’s school had a small student population, 78 students in the combined 6th, 7th, and 8th grade. The school only had a single computer lab, and Teacher G was the only mathematics teacher. The class I observed was considered to be the “on-target” 7th grade class and had a total of 14 students. In her post-unit phone interview, Teacher G categorized these students to being average or slightly above average compared to other 7th grade classes she had taught in the past. The class met daily at 10:50 am and the class period was typically 45 minutes long. Teacher G also taught a smaller remedial 7th grade mathematics class in the period directly following the on-target observed class. Teacher G did not use the entire SimCalc unit with her remedial class but did use a few of the SimCalc lessons with them.

I spent a total of eleven instructional days observing Teacher G’s class. The majority of this time (eight out of eleven days) was spent in the school’s computer lab. When Teacher G used the computer lab, the students would first gather in their usual classroom space before being led across the hall to the lab. The computer lab (Figure 11) was arranged with student computers lining the perimeter of the room, such that when students were using the computers they were facing the walls with their backs to the center of the room. In the computer lab there were more computers than students, so each student could have a computer if they chose to. There was also a teacher computer located in the center of the room that was connected to a projector. Teacher G did not always make use of the teacher computer for every lesson, but when she did she would use it to project a SimCalc MathWorlds simulation onto the wall. When Teacher G was not using the teacher computer she would stand and walk around the computer lab.

Four of the eleven days were spent in Teacher G’s usual classroom due largely to computer-lab scheduling conflicts. The teachers and principal in the school managed computer lab scheduling using a physical paper calendar that remained by the teacher computer at the center of the lab space (represented in Figure 11). Teacher G had reserved two and a half weeks of the computer lab at the beginning of the year, however she voluntarily gave up three days of computer-lab time for other teachers’ to use. Teacher G also decided to teach one lesson from her classroom because the lesson she was scheduled to teach did not require student computer use.

Also, four out of the eleven instructional days were shorter than normal, 35 minutes long as opposed to the usual 45. This is because whenever there was a home middle school or high school football game, most Thursdays and Fridays during the fall semester, the school day ended early. Every student from the elementary, middle, and high schools would attend the middle and high school football games. Indeed, most if not all of the Milano residents attended the football games and these were considered an important community event.
Figure 11 and Figure 12 are copied from field notes taken during the course of the observations. Each square represents an available desk, or computer in the case of the computer lab, and colored squares represent where a student sat. Light gray squares indicate female students while dark gray squares indicate male students.

When Teacher G taught SimCalc lessons in the school computer lab (Figure 11), she would first meet her students in her usual classroom. She would then lead her students across the hallway to the computer lab where each student picked a computer to work from. At the beginning of two observed class periods (observation days 6 and 10), Teacher G reviewed what the students had worked on previously and gave a brief introduction to the mathematical topics they would cover that day in her classroom before they went to the computer lab. While the students did not have assigned workstations in the computer lab, Teacher G instructed to her students to sit alternating “boy-girl-boy-girl”.

Once everyone was seated at a workstation in the computer lab, Teacher G would start class by instructing the students on what page in the workbook they should turn to. Typically, she would then lead the class collectively through the lesson activities. The following is a transcript from one of Teacher G’s observed class periods conducted from the computer lab. In the transcript, the class is working on the first two problems in the “Run, Jace, Run” lesson, which requires them to observe a simulation depicting a single runner and fill out a corresponding data table.

[00:04:08.04] Teacher: "Okay, Run the program. Run the program three times without talking. Watch it three times."
[00:04:36.09] Teacher: "Make sure you watch the dot moving across, but make sure you watch the graph also. Do it three times."
[00:05:08.10] Teacher: "Okay we are going to use the graph to answer the questions here. How many seconds has Jace run when he has gone 25 meters? Look at your chart. 25 meters?"
[00:05:26.15] Multiple Students: "Eight"
[00:05:27.14] Multiple Students: "Four"
[00:05:31.13] Multiple Students: "Four" (Multiple students discuss the possible answer, unable to transcribe.)
[00:05:43.26] Teacher says: "You see the chart on the right, page 19? It says 25 meters you fill in four seconds. It took him four seconds."

--Transcript from video 28411_102606_Cam_1

Typically Teacher G would lead the class through the workbook activities as part of a whole-class discussion. As you can see in the example transcript above, Teacher G would read aloud questions from the student workbook and then students would call out answers aloud. Teacher G would also tell the students when they should run the simulation, how many times they should run the simulation, and what aspects of the simulation she wanted them to pay attention to. Most of Teacher G’s class periods in the computer lab were conducted in this manner. However, during two observed class periods (observation days 8 and 10), she divided the class into groups of three and instructed them to work through the lesson activities together. During these class periods, Teacher G circled around the room, checking on what students were writing in their workbooks, and answering student questions as they arose.

When Teacher G taught the unit from her classroom (Figure 12), the students sat in assigned seats arranged in rows. Teacher G would display the MathWorlds software on a TV located in the upper right corner of the class that was connected to a computer on her desk. The students would watch the simulations while Teacher G led the class collectively through the workbook activities. Teacher G would move between the front of the classroom, which was equipped with two white boards, and her desk which was equipped with the only computer in the classroom. The following transcript is an example of how Teacher G would lead her students through SimCalc activities when they were in her usual classroom. In the transcript, Teacher G is leading her students through the third problem of the “A Race Day” lesson (pg. 5 in the student workbook). The students are instructed to watch a simulation of two runners (named “Clara” and “Fatima” in the student workbook) where one of the runners is given a 10-meter head start. They are then asked to describe what they have seen in the simulation and how it relates to a graph representing the runners’ motion. (The following transcript includes dialog from several students in the class, and their names have been anonymized here.)

[00:45:16.09] Teacher: "Lets watch it. Eyes on the TV."
[00:45:21.20] Holly (female student): "Hey, she had a head start."
[00:45:23.17] Denise (female student): "That means Clara's...."
[00:45:29.09] Several students in the class: "It’s a tie."
[00:45:35.14] Denise: "She got a head start."
[00:45:39.19] Teacher: "Eyes on the TV. Mouth closed. Just Watch." (The teacher plays the simulation again.)
[00:45:55.21] Teacher: "One more time. Eyes on the TV. Watch the graph at the same time." (The teacher plays the simulation again.)
[00:46:07.14] Sally (female student): "She was going steeper."
[00:46:11.11] Holly: "So does that mean that Clara got a head start?"
[00:46:19.28] Holly: "Clara got a 10 meter head start."
[00:46:22.15] Teacher: "Okay. And how did the race end?" (Teacher calls on a male student in the class – “Travis”).
[00:46:24.23] Travis (male student): "Tied"
Teacher G typically started SimCalc activities by asking her students to wordlessly watch the simulation on the TV. If she heard students talking while she played the simulation, she would often instruct her students to stop talking by saying, “mouths closed, eyes on the tv.” After she had played the simulation once, she would play the simulation two or three more times and call out certain aspects she wanted her students to pay attention to, like “watch the graph at the same time”.

Unfortunately, it was difficult for many students in the class to see the simulation displayed on the classroom TV. Specifically, while students could see the runners moving across the screen and lines highlighting in the graph, they could not make out specific numbers and graph lines. This made activities that required students to draw their own graphs difficult to complete. In the following transcript the students watch a simulation of two runners (named “Kim” and “Andy” in the student workbook) where the graph view of the runners is hidden. The students are instructed to predict what a graph depicting the two runners’ motion would look like.

[00:46:28.15] Teacher: "Okay they got there at the same time. Right? Who's going faster?"
[00:46:37.29] Sally: "The orange person."
[00:46:39.24] Travis: "Fatima"
[00:46:44.17] Teacher: "How do you know?"
[00:46:46.24] Mike (male student): "you can just tell."
[00:46:48.17] Teacher: "How do you know?"
[00:46:49.11] Holly: "Because Clara got a head start but Fatima started..."
[00:46:59.27] Sally: "Fatima went like this" (Sally makes motions with her arms – moving one arm upwards and to the right.)
[00:47:03.24] Teacher: "Okay."
[00:47:03.24] Holly: "Because they meet. Both of their lines meet."

--Transcript from video 28411_102406_Cam_2
In this example, we see that some students (such as “Mike” in the transcript above) would stand up from their desks and walk closer to the TV in order to better see the simulation, while other students would remain in their seats. We also see that several students in the class had difficulty seeing the graph lines in the simulation. Teacher G uses her mouse cursor to point out the lines in the simulation, and ultimately tells her students where the race stops (at 50 meters in this example) and other important data points her students need to create their graphs.

Table 11. Summary of Teacher G observed lessons

<table>
<thead>
<tr>
<th>Observed Day</th>
<th>Location</th>
<th>Workbook Pages</th>
<th>Lesson Name(s)</th>
<th>Description and Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Classroom</td>
<td>1 - 8</td>
<td>Managing the Soccer Team, A Race Day, Another Race Day, Information Quest</td>
<td>The teacher starts by reading the “Managing the Soccer Tea” introduction to the students, and as a class, they work through the “A Race Day” lesson, completing all of the problems and their subparts (1:a,b,c,d,e,f,g; 2:a,b,c,d,e; 3:a,b,c; 4). The students then complete the “Another Race Day” lesson in small groups. They complete all but the last question subpart of that lesson. Before the students leave, Teacher G assigns the “Information Quest” lesson as homework.</td>
</tr>
<tr>
<td>2</td>
<td>Computer Lab</td>
<td>7, 9 - 11</td>
<td>Another Race Day, Isabella Improves</td>
<td>The teacher gets them started where they left off the previous day in &quot;Another Race Day&quot; and they cover problems 3:a &amp; b on page 7. Then the teacher starts them on &quot;Isabella Improves&quot; (p.9). They complete the whole lesson, problems 1, 2:a,b,c; 3:a; 4:a,b,c. They skip one sub-part of a question: page 10, question 3:b.</td>
</tr>
<tr>
<td>3</td>
<td>Computer Lab</td>
<td>14-18, 19 – 21</td>
<td>Practice Runs, Run Jace Run</td>
<td>This was a shortened class period, due to a home middle school football game. The teacher has them start the &quot;Run, Jace, Run&quot; lesson on page 19 in the student workbook. (At this point, skipping the preceding &quot;Faster than Max&quot; lesson.) The class completes problems 1:a,b; 2:c,e,g (skipping parts d &amp; f); and 3:a,b,c,d,e. They do not complete the entire lesson in this class period, leaving the remaining</td>
</tr>
</tbody>
</table>
Before the class leaves, Teacher G hands them print outs of the “Practice Runs” lesson and assigns it as homework.

<table>
<thead>
<tr>
<th>Class</th>
<th>Location</th>
<th>Lesson</th>
<th>Page Numbers</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>Classroom</td>
<td>Run, Jace, Run: Revisited, Back at the Office</td>
<td>22, 23 – 24</td>
<td>This was a shortened class period, due to a home high school football game. The teacher starts by reviewing the instructions to the “Run, Jace, Run: Revisited” lesson (p. 22) and tells students that will be their homework for the evening. Then the class starts the “Back at the Office” lesson on page 23. They do not complete the lesson, but complete problems 1 (parts a, b, &amp; c) and 2 (parts a &amp; b).</td>
</tr>
<tr>
<td>5</td>
<td>Computer Lab</td>
<td>Slope and Rate</td>
<td>26 – 28</td>
<td>The students and teacher start and complete the “Slope and Rate” by the end of class. However, they skip the last problem of the lesson, problem 3.</td>
</tr>
<tr>
<td>6</td>
<td>Computer Lab</td>
<td>On the Road</td>
<td>29 – 32</td>
<td>From her classroom, before moving to the computer lab, Teacher G instructs her students on what positive and negative slope would look like on a graph. Once the students are moved to the computer lab they start the “On The Road” lesson. They complete most of the lesson before the end of the class period (problems 1; 2:a,b; 3:a,b,c; 4:a,b,c), except for the last problem (problem 5) on page 32.</td>
</tr>
<tr>
<td>7</td>
<td>Computer Lab</td>
<td>Road Trip Records</td>
<td>33 – 36</td>
<td>Teacher G divides her students into three-person groups, and instructs them to work through the “Road Trip Records” lesson. All of the students in the class complete the first two problems on pages 33-24 (1:a,b,c; 2:a,b,c), and a few groups of students complete or partially complete the third problem on pages 35-36 (3:a,b,c,d,e).</td>
</tr>
<tr>
<td>8</td>
<td>Computer Lab</td>
<td>Graphs of Motion</td>
<td>37 – 38</td>
<td>This was a shortened class period, due to a middle school football game. As students walked towards Teacher G’s classroom she stopped them and directed them to the computer lab so...</td>
</tr>
</tbody>
</table>
The entire class period was spent there. She instructed students to work on the “Graphs of Motion” lesson independently, but allowed them to get help from their neighbor. Most of the students only completed the first problem (1:a,b,c) before class ended.

<table>
<thead>
<tr>
<th>9</th>
<th>Classroom</th>
<th>39 – 42</th>
<th>Graphs of Motion, Salary Negotiations, Summer Job Advice</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Teacher G chose to teach from regular classroom because the SimCalc lessons she planned on covering did not require students to watch simulations. Also, this was a shortened class period due to a high-school football game. Teacher G started by briefly reviewing question 2:a on page 39 in the “Graphs of Motion” lesson. She then had her students complete the last problem in that lesson (3:a,b,c,d) on page 40. The class also completed the “Salary Negotiations” lesson on page 41 (problems 1, 2, 3, 4), and completed the first page of the “Summer Job Advice” lesson on page 42 (problem 1:a,b).</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>10</th>
<th>Computer Lab</th>
<th>42 – 44</th>
<th>Summer Job Advice</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>The students in the class are divided into groups of three and instructed to complete as much as the “Summer Job Advice” lesson as possible. Most students complete the first three problems (1:a,b; 2; 3:a,b). However, none of the students complete the entire lesson and most do not complete the last two problems on pages 45 and 46 (problems 4:a,b; 5:a,b,c).</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>11</th>
<th>Classroom</th>
<th>58 - 59</th>
<th>Mathematically Speaking</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>The class starts by Teacher G instructing them to turn to the “Mathematically Speaking” lesson in their workbooks (p. 58). As a class, they work through the lesson, and they complete all of the lesson problems before the end of the class period (problems 1; 2:a,b; 3).</td>
</tr>
</tbody>
</table>

Teacher G’s progression through the SimCalc unit is summarized in Table 11. (A complete description of the SimCalc lessons and student workbook materials can be found in Appendix C). Teacher G taught the majority of the SimCalc unit, but skipped roughly five out of the
twenty-one lessons (“Faster Than Max”, “All about MPG”, “How Far on How Much?”’, “Suiting Up”, and “Manager’s Report”). Also, while Teacher G spent some time on each of the remaining sixteen lessons in the SimCalc unit, she did not always complete them with her class. If Teacher G started a particular lesson with her class one day, but did not complete it, she would typically not go back to it in any subsequent class period. She would move on to the next lesson in the workbook.

5.1.1.1 Teacher G year one interview summary
Teacher G, like all of the teachers participating in the Scaling Up SimCalc study, participated in two, one-hour long post-unit phone interviews conducted by members of the research team at Virginia Tech. In Teacher G’s year one post-unit interview she described some of the differences she noticed in teaching with SimCalc as opposed to her usual curriculum. In particular, Teacher G’s usual curriculum (which she referred to as “the Saxon program”) followed a very predictable pattern where each lesson started with 10 minutes of new instruction followed by 30 problems students would work through for practice. Teacher G said that she had been using the Saxon program for several years, and her students had seen the Saxon approach to mathematics instruction since first grade. Teacher G said her teaching district liked the Saxon program because it resulted in “consistently high standardized test scores”. Comparatively, the SimCalc curriculum seemed very different to Teacher G and her students. Teacher G felt that her students were very interested in SimCalc because they were doing something different than what they were accustomed to. When pushed to describe what was specifically different about the SimCalc program Teacher G responded with the following list of differences:

“Well, the types of homework, the types of discussions that we could have, the software – looking at the computer screens, coming up with your own types of problems, putting in your data, making stories to go along with the pictures that we were talking about and the races, and not necessarily doing 30 problems of homework like usual. You know, it was a break for them [the students]. We worked all during the class. The whole 45 minutes – we worked from start to finish and that was okay with them. And they sometimes had a few problems to do on their own but it wasn’t anything like the norm.” – Teacher G post-unit interview, Year One

Unfortunately Teacher G wasn’t able to use the computer lab as often as she had wanted during year one of the study. Three of her students had discipline problems and had their school computer privileges revoked. This meant that Teacher G either had to leave those students out of the computer lab when she went with the rest of the class, or teach the unit from her classroom where she would run the simulations for her students. Also, because the school football team made it to the state play-offs, Teacher G had even more shortened class periods than she previously anticipated having. Teacher G decided to teach most of the unit from her classroom. In her interview, Teacher G described how she would work through the activities with her students when she taught from her usual classroom. In particular, she describes how she would draw their attention to the simulations she would run:

“I would run the simulations over and over and over and I would have to specify, ‘watch the green dot, okay? The green dot is the car. Don’t take your eye off the green car.’ And we would have to do it several times. Meanwhile, the others [other students] are like,
When asked how the SimCalc materials fit in with her classroom goals and the directions her school has been moving towards, Teacher G said that the Saxon materials didn’t address the concepts that SimCalc addressed. This was one of the reasons she ultimately decided to try the SimCalc materials and participate in the study.

“I wouldn’t say that my Saxon books really address in depth this particular concept which is one reason I wanted to do this [participate in the study]. I didn’t really fit it [SimCalc] in with my math program. It was like an insertion. We’re doing this instead of [Saxon], not in combination with.” – Teacher G post-unit interview, Year One

When pushed to describe which topics in particular she felt SimCalc was addressing more in depth, Teacher G said:

“It’s solving proportions, doing the ratios, the y=kx in their high school math classes – Saxon in my opinion misses the application of those things.” – Teacher G post-unit interview, Year One

In her interview, Teacher G reported that participating in a study like the Scaling Up SimCalc study was not typical and a bit adventurous for her. Typically, she is “pretty cautious” with trying new things. As Teacher G said, “I’m pretty set in my routine because the kids have their routine and I don’t want to disrupt it.” Teacher G reported that when she approached her administration about participating in the Scaling-Up SimCalc study, her principal was supportive. Furthermore, Teacher G said she did not anticipate any difficulty in making use of the computer lab or using the SimCalc materials in the future once the Scaling Up SimCalc study was over.

5.1.1.2 Teacher G year two interview summary

In Teacher G’s year two interview, she described how teaching with SimCalc for the second year compared to the previous year. Teacher G reported that she felt the second year overall was better, because she was “more familiar” with the material. Still, she was surprised a few times during the unit because “it was just a different class [than last year].”

Since no one in her year two classroom had revoked computer privileges, she was able to take her students to the computer lab for hands on access to SimCalc nearly every class period. Teacher G reported that this led to the SimCalc unit taking longer than she anticipated, and in hindsight she “would have given them a little more information upfront rather than have them discover it on their own”.

“A lot of times I tried to let them discover on their own instead of me just laying out the information. So, allowing them to discover things and figure it out by trial and error, it just takes longer…. So I think a lot of it was just the teaching management of the class and me either giving them information or letting them discover it on their own. And that
always takes longer than just, ‘okay here is the information you need to know, go do what you’ve got to do.’” – Teacher G post-unit interview, Year Two

Another consequence of using the computer lab regularly throughout the unit was that often times the students were facing the computers with their backs to Teacher G. This is different from Teacher G’s usual classroom set-up, where the students face the front of the classroom. In her year two interview, Teacher G described this as something she had to adjust to.

“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. So sharing that attention with the computer was I guess an adjustment for me.” – Teacher G post-unit interview, Year Two

Teacher G in her second interview reported again that her principal and the other teachers in her school supported her participation in the Scaling Up SimCalc study. When asked if they would have any problems with her using SimCalc and the computer lab in the future, she reported that she had a fair amount of autonomy as the only mathematics teacher on campus.

INTERVIEWER: “Are they [principal and other teachers] enthusiastic about you continuing [to use SimCalc]?”
INTERVIEWEE: “The are not against me continuing. I don’t know if they are really enthusiastic, its sort of ‘I’m the math teacher’, everybody kind of has their own interest. But, yeah.”
– Teacher G post-unit interview, Year Two

Teacher G was also asked during her interview how she felt about being observed during year two. She responded that she was “nervous in the beginning but it went away”.

5.1.2 Computers on wheels cases – Teachers C and B

Teacher C and Teacher B were two of three 7th grade mathematics teachers in a school with 1044 students in 6th, 7th, and 8th grades. Teacher C and B’s school used a rotating block schedule, so that classes of 45 minutes alternated with classes of 70 minutes. On “blue schedule” days Teacher C would teach her seventh-grade mathematics class for 45 minutes in the morning and Teacher B would teach seventh-grade mathematics for 70 minutes in the afternoon. On “red
schedule” days the time and duration of the mathematics period would switch. (Teacher C’s class meet in the afternoon for 70 minutes and Teacher B’s class would meet in the morning for 45 minutes.) Also, students and teachers in the school were assigned to “teams”. Each team had one seventh-grade mathematics teacher and students on the same team would have similar if not identical schedules.

There was no explicit explanation or policy for how students were assigned to teams, however, from post-unit phone interviews with Teacher C and Teacher B, it was revealed that student assignment to teams was informally driven by their extracurricular activities and academic status. Teacher B was assigned to the team largely populated by students who chose sport or fitness classes as their extracurricular activity. (As Teacher B said in an observation interview, she “got the athletic ones”.) Teacher C was assigned to the team that the majority of the special needs students were assigned. Teacher C reported that the rationale for this assignment was based on the limited number of special needs instructors and the complications involved with coordinating their time on a rotating block schedule. In theory, the special needs instructors could better serve the majority of special needs students if they all had similar schedules. The third team at the school, which had a seventh grade mathematics teacher who dropped out from the Scaling-Up SimCalc project, was considered to be the “GT” or “Gifted and Talented” team.

I spent a total of seven instructional days in both Teacher C and Teacher B’s classrooms. Every day that the teachers taught the unit, their students would retrieve a laptop from a cart located in the class and sit at their desks. In neither classroom were there enough laptops for every student, so the students were grouped into pairs. As you can see from the figure above (Figure 13), the pairing of students was also facilitated by the way both teachers chose to arrange their classrooms. In both classrooms the students were typically assigned to particular seats, however, for the duration of the SimCalc unit Teacher C let her students sit where they wanted. On the last day of observations with Teacher C, she moved the desks into single rows and instructed her students to sit in their “normal” seats. In contrast, Teacher B’s students were always arranged in pairs, even when they were not participating in SimCalc study or using laptops, and had assigned seats throughout the duration of my observations.

Both Teacher C and Teacher B decided to only teach the SimCalc material for a total of seven days and not complete the entire SimCalc unit. They also both decided to supplement their instruction of SimCalc with a pre-unit, which they described as reviewing some of the students’ basic skills and teaching them to solve proportion problems the “traditional” way. (The traditional way being \( \frac{a}{b} = \frac{c}{d} \), as opposed to \( y = kx \) as it is presented in SimCalc.)

### 5.1.2.1 Teacher C observations

**Table 12. Summary of Teacher C observed lessons**

<table>
<thead>
<tr>
<th>Observed Day</th>
<th>Workbook Pages</th>
<th>Lesson Name(s)</th>
<th>Description and Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1 – 7, 9-10</td>
<td>A Race Day, Another Race Day, Isabella Improves</td>
<td>This was a 70-minute class period. The class starts on the “A Race Day” lesson on page 2, and they work through all of the problems in that lesson (1:a,b,c,d,e,f,g; 2:a,b,c,d,e; 3:a,b,c; 4). They also complete all of the problems in “Another Race Day”</td>
</tr>
<tr>
<td>Time</td>
<td>Pages</td>
<td>Lesson Title</td>
<td>Description</td>
</tr>
<tr>
<td>-------</td>
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<td>-----------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>2</td>
<td>10 – 13, 19</td>
<td>Isabella Improves, Faster Than Max, Run Jace Run</td>
<td>This was a 45-minute class period. Teacher C starts by reviewing the students homework (p. 10, 3:a) and then completes the remaining problems in “Isabella Improves” with her students (3:b; 4:a,b,c). She then completes the first page of problems in the “Faster Than Max” lesson on page 12 (1:a,b,c,d), but skips the remaining problems (2:a,b). The “Practice Runs” lesson is assigned as homework (p. 14-18). Before the end of the class period, Teacher C’s class completes the first page of “Run, Jace, Run” on page 19 (problems 1:a,b; 2:c,d,e).</td>
</tr>
<tr>
<td>3</td>
<td>14 – 18, 19 – 23</td>
<td>Practice Runs, Run Jace Run, Back at the Office</td>
<td>This was a 70-minute class period. Teacher C starts by reviewing problem 1:c on page 15 in the “Practice Runs” lesson she assigned for homework the night before. She does not explicitly review any more problems in that lesson, but says that she is taking up the workbooks and “taking that lesson up for a grade”. Then, the class returns to where they left off in the “Run, Jace, Run” assignment (p. 19) on question 2:c. They complete the “Run, Jace, Run” lesson (p. 19-21, problems 2:c,d,e; 3:a,b,c,d,e; 4:a,b; 5:a,b,c), the “Run, Jace, Run: Revisited lesson (p. 22), and the first page of the “Back at the Office” lesson (p. 23, problems: 1:a,b,c).</td>
</tr>
<tr>
<td>4</td>
<td>24-25, 29-30</td>
<td>Back in the Office, On The Road</td>
<td>This was a 45-minute class period. They start on page 24 in the workbook, which is problem 2 in the &quot;Back at the Office&quot; lesson. They finish number 2 (parts a,b,c) but skip the rest of that lesson (3:a,b) and they also skip the &quot;Slope and Rate&quot; lesson (p.26-28). They start the &quot;On the Road&quot; lesson (p.29) and complete problem 1, they also start problems 2:a,b.</td>
</tr>
<tr>
<td>5</td>
<td>30-33, 40</td>
<td>On The Road, Road Trip Records, Graphs of Motion</td>
<td>This was a 70-minute class period. The lesson starts with them reviewing problem 2 (parts a &amp; b) in the &quot;On the Road&quot; lesson (p. 30). They continue with the lesson (p. 30-32, problems 3:a,c; 4:a,b; 5), however the students do not have laptops until 43 minutes into the class period. While they are going over the problems in &quot;On the Road&quot; without the laptops, they skip the problems in the workbook that have to do...</td>
</tr>
</tbody>
</table>
with running SimCalc MathWorlds simulations (problems 3:b, 4:c). After they have gone through the "On the Road" lesson minus the simulations, the teacher has them skip over to page 40 and complete problems 3:a,b,c,d in the “Graphs of Motion Lesson” on their own. After the students get retrieve laptops, the teacher instructs them to watch the simulations they skipped in "On The Road" and to complete the "Road Trip Records" problems with their partner. By the end of the class period they have only completed problem 1:a,b,c in "Road Trip Records" (p.33).

<table>
<thead>
<tr>
<th>6</th>
<th>34 – 36, 37 – 38,</th>
<th>Road Trip Records, Graphs of Motion</th>
<th>This was a 45-minute class period. The teacher starts by reviewing the instructions for problem 2 (p. 34) in the &quot;Road Trip Records&quot;. She tells them that their job for the day is to finish problems 2 (parts a,b,c) and 3 (parts a,b,c,d,e) in &quot;Road Trip Records&quot; and to complete problems 1 (parts a,b,c) in the &quot;Graphs of Motion&quot; lesson on page 37. The teacher gives an additional, teacher-made worksheet to students who finish the assigned work before the end of the class period. Students who have not finished the assigned work are instructed to do so as homework.</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>18, 33 – 38, 58 - 59</td>
<td>Road Trip Records, Graphs of Motion, Practice Runs, Mathematically Speaking</td>
<td>This was a 70-minute class period. The students are no longer arranged into pairs, and at the start of class the teacher asks them to go back to their &quot;old&quot; seats. They start by reviewing problems 3:a,b,c,d,e (p. 35-36) from the &quot;Road Trip Records&quot; lesson and problems 1:a,b,c (p. 37-38) from the &quot;Graphs of Motion&quot; lesson. In the course of reviewing “Graphs of Motion” she calls the students’ attention to problem 3b, on pg 18, in the “Practice Runs”. She then skips to page 58 and works through the &quot;Mathematically Speaking&quot; lesson (problems 1; 2:a,b; 3). Then students are given a teacher-made worksheet and instructed to work independently.</td>
</tr>
</tbody>
</table>

Teacher C’s progression through the SimCalc unit is summarized in Table 12. Teacher C taught up to page 38 (“Graphs of Motion” lesson, problems 1:a,b,c) in the SimCalc unit, and then skipped to the last lesson in the workbook (pages 58 -59). The last lesson in the workbook is called “Mathematically Speaking” and is largely a review of the concepts introduced in the SimCalc unit with an emphasis on identifying proportional versus non-proportional relationships. Throughout the SimCalc unit Teacher C would sometimes skip problems or subparts of problems, or rearrange the order in which she asked students to complete lessons or problems in the workbook. Teacher C would also periodically go back to previous lessons that her students had worked on to either review the concepts or make sure her students had all completed the assigned questions.
During the course of the observation period, Teacher C gave her students two additional worksheets that she created herself or in collaboration with Teacher B. On the sixth day of observation, she gave students in her class an additional worksheet she created in collaboration with Teacher B. The worksheet was similar to the “Run, Jace, Run: Revisted” lesson in the student workbook, and involved matching tables of data to their corresponding graphical representation and formulas. On the seventh and last day of observation, Teacher C gave her students a worksheet she created herself and instructed her students to work independently on it. This worksheet was designed to prepare students for a “unit test” they would be taking the following day, and largely reviewed skills such as finding the unit rate from a table of data as well as solving a/b=c/d type proportionality problems.

The following is a transcript from one of Teacher C’s observations, and represents an example of how Teacher C would typically discuss SimCalc MathWorlds simulations with her students in whole-class discussion. In this transcript, the teacher is leading them through a problem in the “Another Race Day” lesson (p. 6-7 in the student workbook). In the lesson, the students are asked to describe a SimCalc MathWorlds simulation that depicts two runners running a 50-meter race. For this particular simulation, the graph view is hidden from the students and the students are asked to predict what the graph representing the two runners should look like. (The following transcript includes dialog from several students in the class, and their names have been anonymized here.)

[00:36:02.10] Teacher: “Okay here we go. Alright, lets start filling in on number one. This time, when you ran the simulation, what did you see?”
[00:36:23.17] Teacher: “We are filling in on number 1. What did you see on the simulation this time?” (The teacher calls on one male student in the class, referred to as “Mike” in the transcript.)
[00:36:29.19] Mike (male student): “Two boys running.”
[00:36:32.03] Teacher: “Two boys running. Cool.”
[00:36:33.17] Bob (male student): “They went 50 meters.”
[00:36:34.17] Teacher: “They went 50 meters.”
[00:36:36.00] Clare (female student): “They both started at zero.”
[00:36:37.07] Teacher: “Good, they both started at zero. Now you are looking to see where they start. No one got a head start, they both started at zero.”
[00:36:45.21] Teacher: “What else did you see on this one?”
[00:36:47.21] Teacher: “Because lots of you were using the step button.”
[00:36:52.04] Mike: “Oh”
[00:36:53.27] Teacher: “What do you think? What are some things that we could add?”
[00:36:57.22] Mike: “Oh um Kim, he went 5 meters per second. Like at meter 5 it would be 1 second.”
[00:37:09.20] Teacher: “Okay, wait, say that again.”
[00:37:12.16] Mike: “When you hit the step button, he goes 5 every....like he's on the line by fives every time.”
[00:37:17.27] Bob: “Five meters per second.”
[00:37:19.26] Teacher: “so he traveled... at....”
[00:37:26.02] Multiple students: “five meters per second.”
When Teacher C started a SimCalc activity with her students, she would frequently ask her students to run the SimCalc MathWorlds simulations on their own and then ask them to describe what they saw. She would then continue to ask her students probing questions like “what else did you see?” and “what else could we add?” As in the example above, her probing questions would be followed by more questions specific to certain aspects of the simulation that she wanted them to see, such as “what else did you see, because a lot of you were using the step function?” or “who finishes first?”

5.1.2.2 Teacher C year one interview summary

In Teacher C’s year one post-unit interview she discussed some the mathematical topics the SimCalc unit presented and how the unit compared to what she usually taught her students. In particular, Teacher C felt that the SimCalc unit tied the mathematics of rate and proportionality to more graph interpretation and formula finding than what she usually taught, but her students still needed more practice with those skills.

“Page 22, the ‘Run, Jace, Run: Revisited’ was an excellent assignment, matching tables, graphs to the story. It really was great for them to connect, but that was the only practice there was. They really needed more practice learning how to make a formula.” – Teacher C post-unit interview, Year One

Teacher C also felt that the SimCalc unit pushed the students to talk about slope, a mathematical concept that is beyond the required curriculum for 7th graders. Also, she felt that now that she had finished teaching the with the SimCalc curriculum she needed to “backtrack” a little with her students and have them practice solving proportionality problems in the traditional way (i.e. a/b=c/d) since those are the types of problems students will be presented with on the annual TAKS exam.

“But now that we’re finished, I feel like I need to back track a little bit. The kids know how to find unit rate, they’re very good at that. I think we’ve pushed them into talking about slope, things that are not in our text that we needed to cover.” – Teacher C post-unit interview, Year One

“[K]nowing that we have to face the TAKS test in April, they also need to have that just set up a proportion from a story type problem… I think I’m going to move back to some of the word problems that had them setting up proportions and working them out because I don’t feel like they had enough practice on that to be real successful since so much of the TAKS test covers that. They are able to solve so many problems on the TAKS test from setting up a proportion like that.” – Teacher C post-unit interview, Year One
Teacher C also reported on what it was like for her and her students to use the mobile laptop carts. In her classroom, they had a total of 16 available laptops, which meant that most students had to share with a partner. Teacher C said it was a good thing that the students shared laptops, since it meant they “talked about what they needed to know” with their partner, but she was concerned that some students could “slide under the gun” because their partner would answer questions for them. Teacher C also reported that all of her students enjoyed watching the simulations and working with SimCalc MathWorlds. In particular, Teacher C’s “low level kids” were more engaged than usual when they were using the laptops.

“My low level kids were real excited. They seemed much more engaged than they have been on some lessons. I think they felt like they could cope with the software and with what we were doing in class. They were more confident.” – Teacher C post-unit interview, Year One

However, Teacher C was concerned that she could not always see what her students were doing with the laptops, and that she might have had a different experience if she had been using a computer lab where all the student computer screens would be visible to her.

“Just getting around the room was not easy, and we used laptops which was interesting because everybody was facing me, but all their computers were facing the back. So I think if I had done it in a computer lab, I might have had a different perspective on things because I would be seeing what they were all doing… I was hoping as I was moving around the room that the other side of the room wasn’t playing.” – Teacher C post-unit interview, Year One

For Teacher C, signing up for a study like the Scaling-Up SimCalc was a bit “unusual” and adventurous for her, but she was encouraged to sign-up for the study by her Mathematics Coordinator. Teacher C reported that her Mathematics Coordinator was very much a supporter of technology and education research, and encouraged the teachers at their school to try new things. Teacher C said there was a “big push” to use technology in her district, and she felt that her administration and colleagues were supportive of her participating in the study and using the mobile laptop carts.

5.1.2.3 Teacher C year two interview summary

In Teacher C’s year two interview, she discussed how she felt the second year of teaching with SimCalc compared to her first in terms of the instructional decisions she made, her own comfort level with the curriculum, and the type of students she had. Teacher C reportedly felt more comfortable with the SimCalc curriculum after having taught with it once before. She said that this allowed her to anticipate the parts of the curriculum her students would likely struggle with and she could then prepare accordingly. Teacher C, in collaboration with Teacher B, also felt comfortable reordering particular SimCalc lessons and creating supplementary material of their own. Most notably, Teacher C reported on her rationale for teaching a “pre-unit” on proportionality before teaching the with the SimCalc resources.

“I think we found after teaching it last year that this year we needed to teach them some of the basic proportionality and just how to set-up a proportion, how to work it out, how
to read a word problem that we could use a proportion to solve, and we didn’t find that connection at the end of it [teaching SimCalc]. And again, I think it’s TAKS test related and it’s our benchmark [test] related. We knew those were the kinds of questions that these kids would be tested over the benchmarks as well as on the TAKS and so we thought like we needed to spend sometime going over some of those basic skills with them.” – Teacher C post-unit interview, Year Two

Teacher C also expressed that she did not feel it was necessary to teach every lesson in the SimCalc unit for her students to benefit. In particular, Teacher C skipped the lesson on “Slope and Rate”, and explained that slope was not on the required curriculum for seventh graders and “rather than struggle through that” she would rather spend more time working on other parts of the SimCalc unit. Teacher C also only taught up to the “Graphs of Motion” lesson in the workbook and said her students were “just done” with the unit then.

Teacher C described her school as being very “TAKS driven” and concerned about raising standardized test scores. Teacher C also described her administration and colleagues as being very research driven. At Teacher C’s school, all of the teachers are required to report on a yearly “ABC self-evaluation”. For the evaluation, the teachers must construct a target research question and demonstrate results via student pre and post-tests. Both Teacher C and Teacher B used the Scaling-Up SimCalc prepared pre and post-tests to conduct their self-evaluations.

“You have to come up with a target question on your teaching and it has to be like a side research project and then you find some way to pre and post test and show the results of whatever you chose to work on, whether it might be differentiated learning or some different teaching strategies and other evaluations for the year. [Teacher B] and I both have used the [SimCalc] pre and post-test and shown that the kids have just done an amazing job before and at the end of the unit.” – Teacher C post-unit interview, Year Two

During her year-two post-unit interview, Teacher C also commented on what it was like for her and her students to be observed. Teacher C reported that on the first day of observations her students were more quiet than usual, but they soon forgot that they were being recorded. Teacher C said that she didn’t mind being recorded but she didn’t like knowing that if a lesson didn’t go so well that “it was on record”. At one point in the interview, Teacher C makes reference to a conversation she and I had at the end of one of her class periods. At the end of every class period with Teacher C (and with all the other teachers I observed) I would ask, “how do think it went today?” to gauge the teacher’s perceptions on the successfulness of the class period. Teacher C believed that during one of these post-class interviews she and I shared a laugh because it was “apparent” that her students did not do as well as she had hoped.

“[Meg] just very tactfully said, well ‘how do think it went today?’ and we laughed because it is very apparent that they just missed it altogether so we tried it again the next day and we had more successes. And she was so sweet. She knew they didn’t get it, she didn’t say a word. So she was funny.” – Teacher C post-unit interview, Year Two
### 5.1.2.4 Teacher B observations

#### Table 13. Summary of Teacher B observed lessons

<table>
<thead>
<tr>
<th>Observed Day</th>
<th>Workbook Pages</th>
<th>Lesson Name(s)</th>
<th>Description and Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>14-15, 18, 19 – 21, 22</td>
<td>Practice Runs, Run Jace Run, Run Jace Run Revisited</td>
<td>This was a 45-minute class period. Teacher B had worked through the first lesson few lessons prior to the start of observations, and on this particular day she starts by reviewing the &quot;Practice Runs&quot; lesson on page 14. She works through problem 1 and its subparts (a,b,c,d) and problem 3b explicitly with her students. They then start the &quot;Run, Jace, Run&quot; lesson on page 19. They work through most of the first three problems (1:a,b; 2:c,d,e,f; 3:a,b,c,d), then skip problems 3:e and 4:a,b. By the end of the class period teacher B works through problem 5 (parts a,b,c) on page 21 with her students. For homework, she assigns the “Run, Jace, Run: Revisited” lesson on page 22.</td>
</tr>
<tr>
<td>2</td>
<td>22 - 25</td>
<td>Run Jace Run Revisited, Back at the Office</td>
<td>This was a 70-minute class period. The class starts by reviewing the answers for &quot;Run, Jace, Run: Revisited&quot; on page 22, which was assigned as homework the night before. Then the class starts on the &quot;Back at the Office&quot; lesson, starting on page 23. They complete all of the problems and their subparts (1:a,b,c.; 2:a,b,c; 3:a,b) in that lesson before the end of the class period.</td>
</tr>
<tr>
<td>3</td>
<td>25, 29 – 31</td>
<td>On the Road</td>
<td>This was a 45-minute class period. Before the class starts working on SimCalc activities, the teacher takes 20 minutes to review concepts they have learned. This includes reviewing problem 3 (parts a,b) in the “Back at the Office” lesson (p.25). They then skip the “Slope and Rate” lesson and begin “On The Road” (p.29). The complete the first three problems before the end of class (1; 2:a,b; 3:a,b,c).</td>
</tr>
<tr>
<td>4</td>
<td>31 – 36</td>
<td>On the Road, Road Trip Records</td>
<td>This was a 70-minute class period. The class starts by reviewing problem 3 (p. 31, parts a,b,c) and completing problem 4 (p. 32, parts a,b,c) in “On The Road”. They skip the last problem of that lesson (problem 5), and complete the next lesson, “Road Trip Records” (1:a,b,c; 2:a,b,c; 3:a,b,c,d,e), before the end of the period.</td>
</tr>
<tr>
<td>5</td>
<td>37</td>
<td>Graphs of Motion</td>
<td>This was a 45-minute class period. Teacher B doesn’t have the students use their workbooks until 35 minutes into the class period. Prior to that she gives them “challenges” where she describes races</td>
</tr>
</tbody>
</table>
and the students draw a corresponding graph on mini-whiteboards she passes out to the class. Before she starts the “Graphs of Motion” lesson with the students, she tells students to put away their laptops due to discipline problems. They complete problem 1:a (p.37) without using SimCalc MathWorlds before the end of the class period.

<table>
<thead>
<tr>
<th>6</th>
<th>38 - 40</th>
<th>Graphs of Motion</th>
<th>This was a 70-minute class period. Teacher B starts by going over problem 3, parts a,b,c,d (p. 40) in the “Graphs of Motion” lesson with the whole class. She then tells them to complete problems 1:b,c and 2:b with their partners. Before the end of class, Teacher B reviews those problems in a whole-class discussion, and also goes over the answers to a supplemental homework assignment she gave out the week before.</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td></td>
<td>Teacher’s own materials</td>
<td>This was a 45-minute class period. Teacher gave students a worksheet she created reviewing the SimCalc concepts and designed as test practice. The students worked independently and quietly throughout the period, then regrouped in the last twenty minutes of the period when Teacher B reviewed the worksheet answers.</td>
</tr>
</tbody>
</table>

Teacher B’s progression through the SimCalc unit is summarized in Table 13. Teacher B taught up to page 40 in the SimCalc unit and like Teacher C, Teacher B would periodically skip and re-order lessons or parts of lessons. On the fourth day of observations, Teacher B gave her students the worksheet she created with Teacher C based off the “Run, Jace, Run: Revisited” lesson as homework. During the seventh and last observation period, the students worked independently on a worksheet that Teacher B created. The worksheet summarized the concepts introduced in the SimCalc unit and was designed to resemble the SimCalc post-test the students would be taking the next day. Teacher B even instructed the students to work independently on the worksheet for the first 20 minutes of the class period “as if it were a test” so they could get a better idea of what the “testing situation will be like” the next day.

The following is a transcript from one of Teacher B’s observed periods, and it represents a typical example of how Teacher B would introduce and discuss a SimCalc MathWorlds activity with her students. The transcript starts with Teacher B introducing the second problem in the “On The Road” lesson (p. 30 in the student workbook). The students are asked to examine a graph and a SimCalc MathWorlds simulation depicting the motion of a bus and a van on a road trip. The students are then asked to describe the road trip in a short story. (The following transcript includes dialog from several students in the class, and their names have been anonymized here.)
Teacher B: "This says, 'use the file, onroad2.mw, to see what happened on last year's trip,' so real quickly, lets go to onroad2.mw. In your computer, onroad2, and lets look at the simulation and the graph of what happened."

Teacher B: “Shhhh”

Teacher B walks over to the laptop by the teacher desk and loads the onroad2.mw simulation. The simulation is projected on a pull-down screen behind the teacher desk. She runs the simulation once.

Multiple students in the classroom are talking as they bring up the simulations on their computers

Teacher B: "Okay guys"

Teacher B: "Okay, Run the simulation...shhhh....Run your simulation and see what happens. Run it through once and watch....shhhh....." (Teacher B puts her finger over her lip as she shushes the class.)

Teacher B: "Okay....shhhh....Now guys, I want you to take a second moment and take it back to the beginning and use the step button. Notice what is happening each step along the way, because I'm going to ask you about what you saw in just a second."

Teacher B: Shhhhhh

Teacher B: "Okay just a second, Grace." (Teacher B calls on a female student in the class.)

Grace (female student): "Well it all started when they were at the beginning and they were at about the same speed, and then when they got to Fort Worth, it was like, the bus started slowing down, so then the red car caught up and they were there at the same time."

Teacher B: "Almost exactly right, but there was one little thing that wasn't quite right..."

Teacher B: "Sorry, the red car was behind the bus."

Title (male student) says "The bus was faster"

Teacher B: "Whoa Whoa Whoa Whoa, Just a minute, just a minute, shhhhh...."

Teacher B: "Everything she said was right except for one little piece of information. What was it?" (Teacher points to one male student in the class, Tim).

Tim (male student): "The bus was going faster and then it slowed down."

Teacher B: “The bus is going a little bit faster than the van initially, and then something happened, I think Fort Worth traffic too, but I don't know that, that seems to make sense to me. And then the bus starts slowing down, and then the van keeps going.... What would you say about the van?"

Multiple students: "Constant speed"

Teacher B: "Constant speed, that's right."

--Transcript from video 27913_112906_Cam_2

At the start of each SimCalc activity, Teacher B would typically ask her students to first run the simulation on their own while she would simultaneously run the simulation on the projected teacher computer. She usually only ran the simulation once on the teacher computer. She would then ask the students to run the simulation again, calling out a particular aspects of the simulation she wanted them to pay attention to, or in the case of the example above, a particular
functionality of SimCalc MathWorlds she wanted them to use like the step function. If students were talking during this time, she would typically shush them and request for them to be quiet as she did in the transcript above. Once the students had watched the simulation, Teacher B would call on individual students in the class to explain what they saw.

5.1.2.5 Teacher B year one interview summary

In Teacher B’s first year interview, she described her perception of the SimCalc materials and how it differed from the ways she usually taught rate and proportionality to seventh grade students. Teacher B said that SimCalc made a strong connection between rate and proportionality with representations in graphs, which was a connection that she previously hadn’t thought of incorporating into her teaching. She also said that SimCalc “made it very easy to discuss slope,” a topic she typically wouldn’t introduce to seventh grade students.

Teacher B also discussed her students’ response to the SimCalc materials. She reported that her student enjoyed using the laptops, and she felt that her students got a lot out of SimCalc MathWorlds from just playing with the simulations.

“It let them move the lines up and down and they realized what made things go backwards and that whole thing. [SimCalc MathWorlds] had a real strong association. A real strong visual.” – Teacher B post-unit interview, Year One

Teacher B described her school as being a “techy kind of environment” and said that the teachers were encouraged by the administration to use technology with their students. When she originally signed up for the Scaling-Up SimCalc study, Teacher B had wanted to make use of one of the school computer labs for the project. However, due to scheduling difficulties, Teacher B instead had to use one of the mobile laptop labs.

“You know, when the whole thing started, I was kid of undone that we got the laptops instead of the computer lab because I had really wanted the lab so they could each have their own and I just – you know, you can kind of keep an eye on everyone better when you are in the computer lab….Then when we actually got underway with the laptops I though, ‘you know, this is ever so much better because they’re always going to be talking about it then’ and even though I didn’t have that kind of situation where I could see exactly where they were at all moments unless I went to the back of the room, I also had the possibility of stopping, putting a graph on the overhead and just talking about it from there.” – Teacher B post-unit interview, Year One

Teacher B also discussed some facets of the SimCalc unit that she would change when she used it with students in the future. In particular, there were sections of the SimCalc unit that needed “beefing up” in her opinion. Teacher B felt that her students needed more practice matching tables of data to formulas and graphs. In her interview, Teacher B specifically mentioned the “Run, Jace, Run: Revisited” lesson, and said that she would add more activities like that in the future.

For Teacher B, signing up for a study like Scaling-Up SimCalc was a bit unusual for her. She said that if she hadn’t been encouraged to participate in the study by the Mathematics
Coordinator at her school that she likely wouldn’t have participated at all. Teacher B also reported that her administration was very supportive of her use of the mobile laptop labs, and she didn’t anticipate any problems in using SimCalc or the laptops in the future.

5.1.2.6 Teacher B year two interview summary

In Teacher B’s year-two post-unit interview, she described her rationale for skipping parts of the SimCalc unit. In particular, both Teacher B and Teacher C skipped the lesson on slope because it was not a 7th grade TEK and they felt they needed to move on to other topics. Also, Teacher B only taught to page 40 of the student workbook because she felt they had spent enough time on rate and proportionality by that point and “the point they needed to gain from the [SimCalc] unit was made by then.”

Teacher B and Teacher C also both taught a pre-unit on proportionality before beginning the SimCalc unit. The pre-unit largely focused on “traditional” proportionality, which Teacher B described as solving word problems that required finding two equivalent fractions (a/b = c/d). Teacher B said that teaching a pre-unit first made the SimCalc unit much more “doable” for her and her students. She attributed this to making sure her students knew what they needed to know about proportionality first before seeing it represented in a graph.

“I made sure they understood what I felt they needed to know about proportionality before I brought in the actual visual of it and how the graph of it looks and how a table is laid out.” – Teacher B post-unit interview, Year Two

Teacher B also reported on what it was like for her students to use and share the laptops. Specifically, Teacher B said that she really liked having her students arranged in pairs, because it meant they could talk about what they were doing with one another. Even if there were enough laptops for them to each have their own, Teacher B reports that she would still have her students arranged in pairs.

“I would do that either way. Even if they had their own laptops I would still push the desks 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 and talking about how they did it and why it worked that way. So even if it were possible, even when they had their own [laptop] I would still put them in pairs.” – Teacher B post-unit interview, Year Two

Teacher B, as well as Teacher C, used the Scaling-Up SimCalc pre- and post-test for her “ABC self-evaluation” that every teacher in the school must conduct. She said that she really appreciated not having to create a testing instrument herself, and that her assistant principal was very pleased with the data she gathered and the quality of the study. Teacher B’s assistant principal is former mathematics teacher, and was especially interested in the SimCalc study. In fact, after the assistant principal saw the results from Teacher B and Teacher C’s first year ABC evaluation on SimCalc, she encourage the other mathematics teachers in the school to make use of SimCalc materials even though they weren’t participating in the study.
5.1.3 One laptop and projector case – Teacher M

I spent a total of four instructional days observing Teacher M’s classroom. Teacher M was one of four mathematics teachers in a school with 267 students in 6th, 7th, and 8th grades. Teacher M was assigned to teach mathematics for all three grade levels, and during the year I observed her she was only assigned to teach one 7th grade mathematics class which was considered advanced (labeled “Gifted and Talented” or “GT” for short). Teacher M’s GT, 7th grade mathematics class met everyday for “homeroom” and first period from 8am to 9am. For the first 10 minutes of the class the students and teacher would go over homeroom responsibilities, such as recording attendance, reciting the pledge of allegiance, reciting the Texas pledge of allegiance, listening to announcements led by the principal over the loud speaker, and passing out/eating hot breakfast from the cafeteria. The remaining 50 minutes was the scheduled time for the actual mathematics class.

There was very little time after the class period to talk with Teacher M, but I often had ample time to observe and interview her before the first period started and while I set-up my cameras and microphones. Each day, before class began, Teacher M cleaned the students’ desks with lavender scented cleaning solution. She said the lavender smell “calmed them down” and that clean desks made for healthier students. Also, the students in Teacher M’s class had daily assigned seats, but it was acceptable for students to move their desks to a location where they could better see the front of the classroom. If students in the classroom moved their desks then I would indicate this in the class diagram with arrows. Two students in Teacher M’s classroom would frequently move their desks so they might see the projected simulation better and this is indicated in the figure above (Figure 14).

Every day that the teacher taught the unit, she displayed the MathWorlds software on a single laptop at the front of the class through a projector. The teacher assigned one male student to be in charge of the laptop for the entire unit, and that student would take directions from the teacher (and sometimes other students) on when and how to run the simulations for the entire class. The male student was observably proficient at using the SimCalc MathWorlds software. The teacher rarely instructed him on how to accomplish a task using the software and frequently complimented him on his ability to “figure it all out” with regards to using SimCalc MathWorlds.
Teacher M also employed an overhead projector, on which she would display transparency copies of the student workbooks. The class as a whole would work through each activity collectively, and Teacher M would call students up to the overhead to fill in pieces of the workbook. Below is an example transcript from Teacher M’s class. This transcript represents a typical example of how Teacher M would lead her students through SimCalc activities. (The following transcript includes dialog from several students in the class, and their names have been anonymized here.)

[00:16:07.19] Teacher: “alright, what do you want to do first? Run the race, or wait to see it? Do we need to run it first?”
[00:16:10.28] Teacher: “want to run it first? okay, lets do it. Run it.”
---(The male student assigned to the laptop runs the simulation on the overhead projector)---
[00:16:36.16] Teacher: “what happened?”
[00:16:37.29] Clara (female student): “she stopped”
[00:16:40.23] Teacher: “where did she stop at?”
[00:16:41.27] Tom (male student): “at 6 seconds.”
[00:16:43.25] Teacher: “at 6 seconds, and at what distance?”
[00:16:46.13] <Unable to transcribe, multiple students say numbers> 
[00:16:49.24] Teacher: “about 30 and....let me see.” (Teacher M stands up and uses a measuring stick to gesture to the simulation on the overhead projector.)
[00:16:55.17] Teacher: "right in here...Yea cause its not quite half-way, is it?"
[00:16:57.27] Michael (male student): "no"
[00:16:58.23] Teacher: "and then looking at our little symbol here... yea... what do you think, 33 or 32?"
[00:17:06.20] Multiple students in the class: "33"
[00:17:06.20] Multiple students in the class: "32"
[00:17:09.05] (Clara laughs)

As illustrated by the sample transcription above, Teacher M would frequently ask her students questions such as “what do you want to do?” or “what do we do next?” before a simulation was run. Also, once the simulation had been run she would frequently ask the students general questions about what they saw such as “what happened?” and then more specific questions such as “where did she stop?”

Teacher M would also periodically joke with her students. These jokes were typically off topic, or not pertaining to the mathematics being taught. Frequently, Teacher M would joke with her students during slow or down periods of time in the class, such as when the class was waiting on the student assigned to fill in the overhead transparency to finish or for the boy assigned to run SimCalc MathWorlds to load the next simulation. Below is an example of Teacher M joking with one of the students filmed with the student-focus camera. The joke takes place while a student assigned to the overhead transparency projector is marking points and drawing lines on a graph.
[00:13:15.01] (All of the students visible in the student-focus camera angle are looking down at their workbooks. The female student in the front row of the quad, referred to as “Margie” in the transcript, seems to be drawing in the margin of her workbook. Margie is wearing star-shaped sunglasses as part of her homecoming costume. The boy sitting next to Margie, referred to as “Jon” in the transcript, is tapping his pencil on his desk.)

[00:13:32.19] Teacher says: “Margie, I like your glasses.”

[00:13:33.02] Margie says: “Thank you.”

[00:13:35.05] Teacher says: “Very cool. You are a star.”


[00:13:40.22] Teacher says: “Is that one star for you and one star for Jon?”

[00:13:43.23] (Margie looks over at Jon and laughs.) Margie says, “Yea, I guess.”

[00:13:50.16] Female student off camera says to Margie: “Just ignore her, you're fine.”

[00:13:55.03] (The teacher starts to laugh.)

[00:13:59.03] Margie says: “I'm not selfish, I can share.”

[00:14:00.16] Teacher says: “Aww, aren’t you're precious.”

[00:14:07.03] Teacher says: “Jon’s like ‘oh gosh, stop talking.’”

[00:14:10.08] (Margie laughs. Jon is smiling.)

[00:14:11.24] Student at the transparency says: “Finished.”

[00:14:12.24] Teacher says: "Finished, yay, alright...Children, does yours look like that?"

In this example, Teacher M comments on part of Margie’s homecoming costume and jokingly asks if one star is for Margie and one star is for Jon, the male student who sits next to Margie every class period. Margie, it seems, appreciates and plays along with Teacher M’s joke. As soon as the student at the transparency projector says “finished”, Teacher M returns to discussing a SimCalc workbook activity.

### Table 14. Summary of Teacher M observed lessons

<table>
<thead>
<tr>
<th>Observed Day</th>
<th>Workbook Pages</th>
<th>Lesson Name(s)</th>
<th>Description and Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>12 – 18</td>
<td>Faster Than Max, Practice Runs</td>
<td>The class starts at the beginning of the “Faster Than Max” lesson on page 12, and they complete all of the problems and sub-problems (1:a,b,c,d; 2:a,b). They then work through most of the “Practice Runs” lesson starting on page 14 (1:a,b,c,d; 2:a,b,c). The teacher begins on the last problem in Practice Runs (page 18, problem 3:a,b), but they are unable to complete it. She assigns that as student homework.</td>
</tr>
<tr>
<td>2</td>
<td>18 – 23</td>
<td>Practice Runs, Run Jace Run, Run Jace Run Revisited, Back</td>
<td>The teacher starts by reviewing the homework she assigned, the last problem of the “Practice Runs” lesson (p. 18, 3:a,b). They then complete the “Run, Jace, Run” lesson starting on page 19 (1:a,b;</td>
</tr>
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<td>---</td>
<td>---</td>
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<td></td>
</tr>
<tr>
<td>3</td>
<td>24 – 27</td>
<td>Back at the Office, Slope and Rate</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>26 – 28</td>
<td>Slope and Rate</td>
<td></td>
</tr>
</tbody>
</table>

At the beginning of this class period Teacher M asked students to finish what she called “benchmark tests” and gave them 15 minutes. After that she finished the “Back at the Office” lesson starting on page 24 (2:a,b,c; 3:a,b) and then started the “Slope and Rate” lesson on page 26 (1:a,b). At the end of the class period she instructs the students to leave their workbooks on their desks, she is collecting them to grade.

This class period was shortened (25 minutes) because of the homecoming pep-rally be held in the afternoon. Teacher M started by briefly reviewing what was done on page 26 of “Slope and Rate”, then continued the lesson on problem 1:c. They completed problems 1:c,d,e,f and 2. They did not complete the last problem of the lesson (problem 3) on page 28.

A summary of the lessons taught in Teacher M’s classroom while I conducted observations can be found in Table 14. At the start of each of Teacher M’s observation periods she would ask the students to turn their workbooks to the last page they were on in the student workbooks. She would typically briefly review what they had covered the previous day and then move on to the next problem. Unfortunately, I was unable to observe Teacher M and her students for the entire duration that they used the SimCalc unit. However, from the observation interviews, post-unit phone interviews, and teacher log data we know that Teacher M taught with the SimCalc materials for a total of 8 days, which was broken up by mid-semester benchmark testing. Teacher M also covered the majority of the SimCalc material, only skipping a few items in a few of the lessons.

**5.1.3.1 Teacher M year one interview summary**

In Teacher M’s year one post-unit interview, she described the sequence of events that led to her decision to only use one laptop connected to a projector for the SimCalc unit. There was an initial problem with installing SimCalc MathWorlds on the computer lab machines, and it was difficult to have the problem corrected because the computer tech that helped with the installation had limited time.

“When our computer tech installed it [SimCalc MathWorlds], it wasn’t reading the files. I had no files [simulation files]…So they [the SimCalc research team] emailed the files to me and he was able to install it into my laptop and I used the laptop and projected it out and that’s how we did the whole project. Because, some days, trying to get it into the other computers, and trying to get him [the computer tech] here to get it done was
mission impossible because we only have two computer techs for the whole district and they moved our server so we’ve had all kinds of craziness. … I didn’t want to take any chances and struggle and waste time – valuable time – with them [the students] trying to get on the computer individually. I mean, we didn’t have that kind of time. With all the interruptions, every minute was precious. So we worked on, steamed ahead. We were good!” – Teacher M post-unit interview, Year One

Despite the initial set-backs with using the SimCalc MathWorlds software, Teacher M reported that she and the students were very happy and engaged with the SimCalc curriculum. Teacher M still felt that it was important for her students to be engaged with what was happening in the SimCalc simulations, and reported that she structured her instruction such that the students were “in control of the laptop”.

“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, where to look, how to get it…. Once they got into it, they were teaching themselves and teaching each other and telling me what to do, which was totally awesome because that’s what I wanted. But they had to have guidance – little bit of guidance.” – Teacher M post-unit interview, Year One

In her interview, Teacher M even described some of the jokes she shared with her students while working through the SimCalc curriculum. To Teacher M, joking with her students was one of the ways she helped her students relate to the mathematics they were trying to learn.

“Well you know, it’s like – it’s a man thing. You take a trip and you try to figure out your miles per gallon and I said ‘I really do think this is a man thing. Because me, as long as I have gas, I don’t care.’ That’s just a woman-thing I think because I don’t know too many women who do all this miles per gallon ‘wooo, I’m going so far on this tank’ or whatever. And we’ve talked about it and joked about it and they’ve said, ‘yeah, I think that is my dad.’ And they could relate to this, and if I could make it relate to something that they know – the experience – it was something they could really get their teeth into it and they were all gung ho to learn more about it.” – Teacher M post-unit interview, Year One

Teacher M also reported that at times she would deliberately make mistakes when she was at the front of the classroom to see if her students would correct her. In particular, Teacher M expressed that she was very pleased with her students grasp on the concept of slope, and the way she assessed their understanding of the topic was by making deliberate mistakes.

“I would mess up the numbers and I’d put the run over the rise and it was like instantly, they were on me like ants. I’m telling you. They were correcting me saying, ‘no, no, no, that’s wrong. It is rise over run.’ … I made mistakes like that on purpose for them to see if they are on me and are listening and if they’re understanding the concepts.” – Teacher M post-unit interview, Year One
Teacher M also described herself as pretty adventurous for a teacher, and that she was willing to “try just about anything at least once”. Teacher M also readily sought out and used educational technologies with her students. Two years prior to her involvement with the Scaling Up SimCalc study, Teacher M had written and received funding for a half-million dollar grant that provided for what she called a “mini lab”. The mini lab contained fifteen playstations and eight computers equipped with a variety of different educational software and games. Teacher M expressed in her interview that educational technology, like SimCalc MathWorlds and the games in her mini-lab, are beneficial because they are engaging for students. Her principal, who was brand new the first year of the SimCalc study, was also very supportive of Teacher M’s use of technology in the classroom and had even observed Teacher M one day while she taught with SimCalc.

5.1.3.2 Teacher M year two interview summary
Teacher M did not try to use the computer lab at all during the second year of the study, and again made use of one laptop connected to a projector. When asked why she didn’t try taking them to the computer lab she replied simply that “taking turns on the laptop was fine” and “this was easier to control” with her large class (25 students).

“That’s the reason why I kept them under control. It was too large and you would lose some of them. Some of them would never get it. In this way, I made sure everybody was together and no child was left behind.” – Teacher M post-unit interview, Year Two

In her year two post-unit interview, Teacher M again expressed the belief that her students were in control of what was going on in the classroom and that she would just guide them to “where they needed to be.”

“I just kind of guided them where they needed to be sure that they were and find the answers you like ‘how did you think they did this?’ or ‘why did they do that?’ that kind of guidance. And I said, ‘okay so what are we saying here?’, “what are we going to do?” That kind of stuff, because I mean they really almost did it themselves. It was almost self-paced. I just made sure they were on the right road, because they are so easy to get off on the wrong road and often to something else, la-la land.” – Teacher M post-unit interview, Year Two

Teacher M had another brand new principal during the second year of the study. This principal was formerly a math certified teacher, and she was very supportive of Teacher M’s use of SimCalc. In fact, the principal wanted the other teachers in the school to use the SimCalc materials with their students, even those students in 6th and 8th grade.

5.2 Descriptive statistics from initial coding analysis
After the videos had gone through the initial coding process, the codes were quantified and entered into an excel file. Depending on the type of code, a frequency or duration was calculated. Codes relevant to time, such as class start and class end or technology use start and technology use end, were used to determine durations. Codes relevant to frequencies of occurrence, such as resource use or discussion, were counted by a researcher and recorded for each class. For student technology and workbook use, frequencies were determined and recorded for each student viewable in the video.
5.2.1 Class time

All tapes were coded for “Class Start, Initiated”, “Class Start, Actual”, “Class End, Initiated” and “Class End, Actual.” Class Start, Initiated meant that the teacher began to call the class to order, and Class End, Initiated meant that the teacher asked the students to begin cleaning up and shutting down for the day. Class Start, Actual meant that classroom instruction actually began either via the teacher’s initiation or because students visibly started to work in their workbooks or on the computer. Class End, Actual was signified by the students shutting down their computers, putting their materials in their book bags, or standing up and leaving. Table 15 shows the average actual class instruction length for each classroom, measured by the duration in minutes between when Class Start, Actual was coded and Class End, Initiated was coded.

Table 15. Average actual class instruction in minutes

<table>
<thead>
<tr>
<th>Teacher</th>
<th>Total # of Observed Days</th>
<th>Scheduled Class Time (minutes)</th>
<th>Average Actual Class Length (minutes)</th>
<th>Total Minutes Math Instruction Over Entire Observation</th>
</tr>
</thead>
<tbody>
<tr>
<td>M</td>
<td>4</td>
<td>50</td>
<td>44.5</td>
<td>178</td>
</tr>
<tr>
<td>C</td>
<td>7</td>
<td>45 for 3 days 70 for 4 days (Avg: 59.3)</td>
<td>Scheduled 70 min: 56 Scheduled 45 min: 40.9 (Total Avg: 49.5)</td>
<td>346.6</td>
</tr>
<tr>
<td>B</td>
<td>7</td>
<td>45 for 4 days 70 for 3 days (Avg: 55.7)</td>
<td>Scheduled 70 min: 62.8 Scheduled 45 min: 43.2 (Total Avg: 51.6)</td>
<td>361.2</td>
</tr>
<tr>
<td>G</td>
<td>11</td>
<td>45</td>
<td>38.2</td>
<td>419.6</td>
</tr>
</tbody>
</table>

Teacher G had the shortest scheduled class periods, and as described above (in Section 5.1.1), would sometimes have even shorter class periods due to middle school or high school football games. Teachers C and B had the highest average scheduled class times with their students, and over the course of the observations Teacher C had slightly more scheduled class time due to their alternating 70 minute and 40 minute period rotation schedule. On average, the teachers used within 5 to 10 minutes of their scheduled class period time for instruction. On some observation days, the video recorder stopped prematurely and did not record the Class End, Initiated or Class End, Actual times. In order to assess approximate measures of how much class period time was spent on start-up and winding down tasks, the average difference between Class Start, Initiated and Class Start, Actual as well as Class End, Initiated and Class End, Actual was calculated where the observation record was complete.

Table 16. Average class start-up and wind down times

<table>
<thead>
<tr>
<th>Teacher</th>
<th>Avg. Class Start-up Time (minutes)</th>
<th>Avg. Class Wind down Time (minutes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>M</td>
<td>4.33</td>
<td>0.10</td>
</tr>
<tr>
<td>C</td>
<td>1.57</td>
<td>0.68</td>
</tr>
<tr>
<td>B</td>
<td>0.96</td>
<td>1.04</td>
</tr>
<tr>
<td>G</td>
<td>1.63</td>
<td>1.0</td>
</tr>
</tbody>
</table>
Table 16 shows the average start-up and wind down times for each classroom, as measured by the video observation data where the Class Start and Class End times have been recorded. Teachers C, B, and G each spent, on average, less than 2 minutes on start-up tasks. Teacher M, however spent roughly 4 minutes, on average, on start-up tasks. This could be, in part, because Teacher M would often have to complete some of her homeroom tasks before she could start instruction. In contrast, Teacher M spent the least amount of time on wind down tasks, largely because her students did not need to shutdown or put away computers and laptops. Teachers C, B, and G each spent, on average, 1 minute on wind down tasks.

5.2.2 Technology resource use

Each time the teachers and students made use of the technology the action was recorded by the appropriate Technology codes (full descriptions of the codes are in Appendix A). When students made a move to use SimCalc MathWorlds, or referenced the technology while talking to a teacher or peer, the action was recorded with the Technology Student Initiated code. When the teacher instructed the students to use SimCalc MathWorlds, or referenced the technology in discussion with a student, the action was recorded with the Technology Teacher Initiated code. Also, the duration the technology was used for during the class period was calculated by using the Technology Use Start and Technology Use End codes. The Technology Use Start code was used to denote when the students loaded the SimCalc MathWorlds software onto their computer (or was displayed via projector or TV in the case of Teacher M and when Teacher G taught from her classroom), and the Technology Use End code was used to mark when students began shutting down their machines. The following table (Table 17) shows the number of observed instructional days the teacher and students made use of technology, as well as the average duration the technology was used for during those class periods.

<table>
<thead>
<tr>
<th>Teacher</th>
<th>Total # of Observed Days</th>
<th># of Days Students Used Tech</th>
<th># of Days Teacher Used Tech</th>
</tr>
</thead>
<tbody>
<tr>
<td>M</td>
<td>4</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td>C</td>
<td>7</td>
<td>6</td>
<td>4</td>
</tr>
<tr>
<td>B</td>
<td>7</td>
<td>6</td>
<td>4</td>
</tr>
<tr>
<td>G</td>
<td>11</td>
<td>7</td>
<td>6</td>
</tr>
</tbody>
</table>

Teacher M, who made use of a laptop and projector at the front of the classroom, used the technology each day she was observed, and the students never directly used the technology. That is, except for the one male student selected to run and manipulate the SimCalc MathWorlds software that was projected overhead. His use of the laptop was recorded as Teacher Initiated Technology use since he only used the laptop as directed by Teacher M and never used the technology independently. In the other classrooms, using mobile laptop carts or the school computer lab, the students used the technology for the majority of days observed. However, there was at least one class period in each of these classrooms where the students did not have access, or make use of, the technology resource.
Table 18. Average amount of time in minutes the students versus teacher used the technology

<table>
<thead>
<tr>
<th>Teacher</th>
<th>Avg. Duration of Student Tech Use</th>
<th>Avg. Duration of Teacher Tech Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>M</td>
<td>0.00</td>
<td>40.11</td>
</tr>
<tr>
<td>C</td>
<td>38.10</td>
<td>19.53</td>
</tr>
<tr>
<td>B</td>
<td>45.33</td>
<td>37.45</td>
</tr>
<tr>
<td>G</td>
<td>23.55</td>
<td>17.63</td>
</tr>
</tbody>
</table>

Table 18 shows the average amount of time that students as compared to teachers actually used the technology resource across the four different classrooms. It shows that in some classrooms, the teacher used the computer as an aide in her teaching (Teacher M), while in others students and teachers spent nearly the same amount of time on the computer (Teacher B), and in yet others, the students spent more time than the teacher (Teacher C and Teacher G). It is especially interesting that Teacher C and Teacher B, who largely made instructional decisions together collaboratively and had nearly identical classroom and technology set-ups, had such different ratios of teacher to student technology use. In Teacher C’s classroom, the students used the technology on average roughly 19 minutes more than Teacher C herself. In Teacher B’s classroom, the students only used the technology roughly 8 minutes more than the teacher on average.

Table 19. Observed teacher and student initiations of technology resource use by observation day

<table>
<thead>
<tr>
<th>Teacher</th>
<th>Obs. Day</th>
<th># Teacher Initiations of Tech Use</th>
<th># of Students Visible in Both Camera Views</th>
<th>Total # Student Tech Use Initiations</th>
<th>Avg. # Student Tech Use Initiations</th>
<th>Min # of Tech Use Initiations by Individual Student</th>
<th>Max # of Tech Use Initiations by Individual Student</th>
</tr>
</thead>
<tbody>
<tr>
<td>M</td>
<td>1</td>
<td>13</td>
<td>5</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>M</td>
<td>2</td>
<td>6</td>
<td>6</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>M</td>
<td>3</td>
<td>2</td>
<td>8</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>M</td>
<td>4</td>
<td>4</td>
<td>6</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>C</td>
<td>1</td>
<td>14</td>
<td>5</td>
<td>23</td>
<td>4.6</td>
<td>1</td>
<td>10</td>
</tr>
<tr>
<td>C</td>
<td>2</td>
<td>14</td>
<td>8</td>
<td>76</td>
<td>9.5</td>
<td>0</td>
<td>19</td>
</tr>
<tr>
<td>C</td>
<td>3</td>
<td>5</td>
<td>9</td>
<td>112</td>
<td>12.4</td>
<td>6</td>
<td>19</td>
</tr>
<tr>
<td>C</td>
<td>4</td>
<td>5</td>
<td>2</td>
<td>16</td>
<td>8.0</td>
<td>2</td>
<td>14</td>
</tr>
<tr>
<td>C</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>22</td>
<td>7.3</td>
<td>5</td>
<td>10</td>
</tr>
<tr>
<td>C</td>
<td>6</td>
<td>2</td>
<td>8</td>
<td>21</td>
<td>2.6</td>
<td>0</td>
<td>6</td>
</tr>
<tr>
<td>C</td>
<td>7</td>
<td>0</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>B</td>
<td>1</td>
<td>4</td>
<td>8</td>
<td>47</td>
<td>5.9</td>
<td>0</td>
<td>12</td>
</tr>
<tr>
<td>B</td>
<td>2</td>
<td>3</td>
<td>9</td>
<td>79</td>
<td>8.8</td>
<td>2</td>
<td>18</td>
</tr>
<tr>
<td>B</td>
<td>3</td>
<td>6</td>
<td>8</td>
<td>54</td>
<td>6.8</td>
<td>0</td>
<td>16</td>
</tr>
<tr>
<td>B</td>
<td>4</td>
<td>9</td>
<td>7</td>
<td>33</td>
<td>4.7</td>
<td>1</td>
<td>11</td>
</tr>
</tbody>
</table>
Table 19 shows the total number of times each teacher initiated technology use in each class period and the average number of student initiated technology use was observed in each class period. For each pair of observation videos for each class period, the total number of students visible to the camera was recorded, as well as the students’ individual number of technology use initiations. From these numbers we are able to record the average number of visible student technology use initiations, as well as the minimum and maximum number of observed tech-use initiations per individual student.

Examining student initiation of technology use reveals that there is diversity amongst class members in how much they use the technology. In Teacher B and Teacher C’s classrooms we can see that it was not uncommon for a student visible to the camera to never initiate technology use, while another student peer would initiate technology use over ten times in the same class period. In one of Teacher C’s observed class periods, one student visible to the camera did not initiate technology use at all while a peer initiated technology use nineteen times. Also, in one observed period with Teacher B a student initiated technology use two times while a peer made use of the technology eighteen times. Since the students in Teacher B and Teacher C’s classrooms shared the laptops, this could indicate that the use of the technological resource may not have always been equitable between student pairs. However, when we look at the student technology use initiations in Teacher G’s classroom we still see disparity between student peers. When Teacher G’s students were in the computer lab they all had access to individual computers, however there were two class periods where at least one student chose not to initiate use of the technological resource at all and a peer used the technology, in one case, up to fourteen times.

5.2.3 Workbook resource use

Each time the teachers and students made use of the SimCalc unit workbook the action was recorded by the appropriate Workbook codes (full descriptions of the codes are in Appendix A). When students made a move to use the SimCalc workbook, or referenced the workbook while talking to the teacher or peer, the action was recorded with the “Workbook Student Use” code. When the teacher instructed the students to turn to a particular page in the workbook, or referenced an activity in the workbook in discussion with a student, the action was recorded with the “Workbook Teacher Mention” code.
Table 20. Number of observed day's classrooms made use of SimCalc student workbooks

<table>
<thead>
<tr>
<th>Teacher</th>
<th>Total # of Observed Days</th>
<th># of Days Teacher Used/Mentioned Workbook</th>
</tr>
</thead>
<tbody>
<tr>
<td>M</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>C</td>
<td>7</td>
<td>7</td>
</tr>
<tr>
<td>B</td>
<td>7</td>
<td>6</td>
</tr>
<tr>
<td>G</td>
<td>11</td>
<td>11</td>
</tr>
</tbody>
</table>

The preceding table (Table 20) shows the number of observed instructional days the teacher directly mentioned the student workbook throughout the course of instruction. This table also corresponds with the number of days students initiated workbook use at least once throughout the class. As expected, the teachers and students made use of the workbook resource every day the SimCalc unit was taught, with the exception of Teacher B who taught one lesson from material she created herself.

Table 21. Observed teacher and student workbook use by observation day

<table>
<thead>
<tr>
<th>Teacher</th>
<th>Obs. Day</th>
<th># Teacher Workbook Mentions</th>
<th># of Students Visible in Both Cams</th>
<th>Total # Student Workbook Use</th>
<th>Avg. # Student Workbook Use</th>
<th>Min # of Workbook Use by Individual Student</th>
<th>Max # of Workbook Use by Individual Student</th>
</tr>
</thead>
<tbody>
<tr>
<td>M</td>
<td>1</td>
<td>13</td>
<td>5</td>
<td>37</td>
<td>7.4</td>
<td>7</td>
<td>8</td>
</tr>
<tr>
<td>M</td>
<td>2</td>
<td>8</td>
<td>6</td>
<td>56</td>
<td>9.3</td>
<td>0</td>
<td>27</td>
</tr>
<tr>
<td>M</td>
<td>3</td>
<td>1</td>
<td>8</td>
<td>66</td>
<td>8.3</td>
<td>1</td>
<td>12</td>
</tr>
<tr>
<td>M</td>
<td>4</td>
<td>3</td>
<td>6</td>
<td>26</td>
<td>4.3</td>
<td>0</td>
<td>12</td>
</tr>
<tr>
<td>C</td>
<td>1</td>
<td>20</td>
<td>5</td>
<td>68</td>
<td>13.6</td>
<td>6</td>
<td>19</td>
</tr>
<tr>
<td>C</td>
<td>2</td>
<td>12</td>
<td>8</td>
<td>42</td>
<td>5.3</td>
<td>0</td>
<td>13</td>
</tr>
<tr>
<td>C</td>
<td>3</td>
<td>9</td>
<td>9</td>
<td>118</td>
<td>13.1</td>
<td>4</td>
<td>21</td>
</tr>
<tr>
<td>C</td>
<td>4</td>
<td>4</td>
<td>2</td>
<td>9</td>
<td>4.5</td>
<td>1</td>
<td>8</td>
</tr>
<tr>
<td>C</td>
<td>5</td>
<td>11</td>
<td>3</td>
<td>33</td>
<td>11.0</td>
<td>8</td>
<td>14</td>
</tr>
<tr>
<td>C</td>
<td>6</td>
<td>2</td>
<td>8</td>
<td>58</td>
<td>7.3</td>
<td>4</td>
<td>15</td>
</tr>
<tr>
<td>C</td>
<td>7</td>
<td>11</td>
<td>3</td>
<td>14</td>
<td>4.7</td>
<td>0</td>
<td>12</td>
</tr>
<tr>
<td>B</td>
<td>1</td>
<td>9</td>
<td>8</td>
<td>114</td>
<td>14.3</td>
<td>2</td>
<td>24</td>
</tr>
<tr>
<td>B</td>
<td>2</td>
<td>15</td>
<td>9</td>
<td>97</td>
<td>10.8</td>
<td>0</td>
<td>24</td>
</tr>
<tr>
<td>B</td>
<td>3</td>
<td>9</td>
<td>8</td>
<td>80</td>
<td>10.0</td>
<td>8</td>
<td>13</td>
</tr>
<tr>
<td>B</td>
<td>4</td>
<td>18</td>
<td>7</td>
<td>87</td>
<td>12.4</td>
<td>7</td>
<td>28</td>
</tr>
<tr>
<td>B</td>
<td>5</td>
<td>2</td>
<td>9</td>
<td>12</td>
<td>1.3</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>B</td>
<td>6</td>
<td>9</td>
<td>9</td>
<td>90</td>
<td>10.0</td>
<td>1</td>
<td>20</td>
</tr>
<tr>
<td>B</td>
<td>7</td>
<td>0</td>
<td>7</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>G</td>
<td>1</td>
<td>20</td>
<td>11</td>
<td>133</td>
<td>12.1</td>
<td>11</td>
<td>15</td>
</tr>
<tr>
<td>G</td>
<td>2</td>
<td>1</td>
<td>3</td>
<td>47</td>
<td>15.7</td>
<td>14</td>
<td>18</td>
</tr>
<tr>
<td>G</td>
<td>3</td>
<td>7</td>
<td>5</td>
<td>55</td>
<td>11.0</td>
<td>9</td>
<td>14</td>
</tr>
<tr>
<td>G</td>
<td>4</td>
<td>7</td>
<td>5</td>
<td>25</td>
<td>5.0</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>G</td>
<td>5</td>
<td>14</td>
<td>3</td>
<td>35</td>
<td>11.7</td>
<td>8</td>
<td>14</td>
</tr>
</tbody>
</table>
Table 21 shows the total number of times each teacher mentioned the student workbook in each class period and the average number student workbook use was observed in each class period. For each pair of observation videos for each class period, the total number of students visible to the camera was recorded, as well as the number of times each student was observed using their workbook. From these numbers we are able to record the average number of visible student workbook use, as well as the minimum and maximum number of observed workbook use per individual student.

Examining student use of the workbook again reveals that there is diversity amongst class members in how much they use this resource. For example, while the average number of times that six students we examined in day 2 of Teacher M’s classroom turned to the workbook was 9.3, one student turned to it 27 times, while another never used it at all. Usually, there was not that much disparity between students in the amount they used the workbooks, but again in the 10th day of observations with Teacher G we had one student who used the workbook 3 times while another student also in our field of view used it 30 times. Similar extremes of student workbook use were observed in Teacher C and Teacher B’s classrooms as well. This indicates that even though each student in every class period we observed had access to their own workbook, they sometimes chose to make use of their workbooks with differing frequency.

5.2.4 Whole class and small group discussion
Each time the teachers were observed initiating whole-class discussions the action was recorded via the “Discussion Whole-Class” code. Also, when teachers engaged in discussions with a singular student or a small group of students the action was recorded using the “Discussion Teacher-Student” code. (A full description of the initial coding scheme is in Appendix A.) The following table (Table 22) shows the average, minimum, and maximum number of times each of the teachers were engaged in whole-class or teacher-student discussions as observed in the classroom videos.
Table 22. Average, Minimum, and Maximum Whole Class Discussion and Teacher-Student Discussion observed per classroom

<table>
<thead>
<tr>
<th>Teacher</th>
<th>Total # of Observed Days</th>
<th>Avg. # of Whole Class Discussions Initiated</th>
<th>Minimum # of Whole Class Discussions Initiated (in one day)</th>
<th>Maximum # of Whole Class Discussions Initiated (in one day)</th>
<th>Avg # of Teacher-Student Discussions Initiated</th>
<th>Minimum # of Teacher-Student Discussions Initiated (in one day)</th>
<th>Maximum # of Teacher-Student Discussions Initiated (in one day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>M</td>
<td>4</td>
<td>3.75</td>
<td>1</td>
<td>5</td>
<td>1.25</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td>C</td>
<td>7</td>
<td>6.57</td>
<td>2</td>
<td>10</td>
<td>2.29</td>
<td>0</td>
<td>5</td>
</tr>
<tr>
<td>B</td>
<td>7</td>
<td>7.29</td>
<td>3</td>
<td>13</td>
<td>4.14</td>
<td>0</td>
<td>12</td>
</tr>
<tr>
<td>G</td>
<td>6</td>
<td>6.73</td>
<td>0</td>
<td>14</td>
<td>11.09</td>
<td>0</td>
<td>35</td>
</tr>
</tbody>
</table>

From the table above, we can see that Teacher M, on average, initiated the least amount of whole-class discussions and the least amount of teacher-student discussion. This corresponds with the way Teacher M led her students through each of the SimCalc activities as a whole-class discussion, with student attention largely focused towards the front of the classroom. Teacher M would initiate whole-class discussion at the beginning of the class period and rarely stop until the end of the class period. Whenever Teacher M moved away from the front of the class to engage in teacher-student discussion, she would soon afterwards return to the front of the class and reinitiate the whole-class discussion. This is indicated by the relationship between the maximum and minimum number of times she initiated whole-class and teacher-student discussions. She initiated whole-class discussion one more time than she initiated teacher-student discussion in any class period.

In comparison, the other observation teachers did not have such a direct relationship between the number of times they initiated whole-class discussion and the number of times they initiated teacher-student discussion. This is because Teacher C, Teacher B, and Teacher G were all observed to have at least some portion of their observed class periods spent in individual or small-student group work where the teacher would walk around the student desks observing the students work and answering student questions. From the table above, we see that Teacher C, Teacher B, and Teacher G initiated whole-class discussion six to eight times a class period on average. Teacher G initiated more teacher-student discussion per class period than any of the other teachers on average and in any one class period. Also, it seems that Teacher B initiated slightly more teacher-student discussions than Teacher C on average.

Table 23. Average, Minimum, and Maximum observed instances of Teacher Directed Moves to Individual or Small Group Work

<table>
<thead>
<tr>
<th>Teacher</th>
<th>Total # of Observed Days</th>
<th>Average observed moves to Individual/Small Group Work</th>
<th>Minimum (in one day)</th>
<th>Maximum (in one day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>M</td>
<td>4</td>
<td>1.5</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td>C</td>
<td>7</td>
<td>1.43</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td>B</td>
<td>7</td>
<td>2</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td>G</td>
<td>11</td>
<td>0.82</td>
<td>0</td>
<td>2</td>
</tr>
</tbody>
</table>
Each time a teacher explicitly directed the students to work individually or in small groups, the action was recorded via the “Individual/Small Group Work” code. Table 23 shows the average, minimum, and maximum number of observed teacher directed moves to individual or small group work. We see from the table above that teachers would typically ask students to work individually or in small groups one to two times a class period. Teacher G initiated the fewest moves to individual or small group work and in any one class period would, at maximum, ask students to work individually or in small groups twice. However, there were a few class periods where Teacher G’s students were instructed to start working on a particular problem set in the computer lab and the students commenced to work individually or in small groups. In these periods, Teacher G did not verbally direct her students to work individually or in small group works, rather the direction to work individually or in small groups was implicit in other directions Teacher G gave her students or the students moved to working individually or in small groups on their own accord. Teachers C, B, and M would ask students to work individually or in small groups anywhere from zero to four times a class period.

<table>
<thead>
<tr>
<th>Teacher</th>
<th>Total # of Observed Days</th>
<th>Average # of Student-Student Discussions Initiated and Observed</th>
<th>Minimum (in one day)</th>
<th>Maximum (in one day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>M</td>
<td>4</td>
<td>1.75</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>C</td>
<td>7</td>
<td>4.57</td>
<td>0</td>
<td>11</td>
</tr>
<tr>
<td>B</td>
<td>7</td>
<td>4.14</td>
<td>0</td>
<td>8</td>
</tr>
<tr>
<td>G</td>
<td>6</td>
<td>8.36</td>
<td>0</td>
<td>35</td>
</tr>
</tbody>
</table>

Each time students were observed to initiate discussion with a student peer the action was recorded using the “Student-Student Discussion” code. Table 24 shows the average number of times student-student discussion was recorded for each of the four observation classrooms. The table also shows the minimum and maximum number of student-student discussions observed in any one class period. We can see from the table above that for each of the four classrooms there was at least one classroom where no student-student discussion was observed. We also see that Teacher M’s classroom had the least number of observed student-student discussions while Teacher G’s classroom had the most. Teacher C and Teacher B, on average, had similar numbers of student-student discussion.

The low number of student-student discussions in Teacher M’s classroom follows from Teacher M’s observed teaching style: where most of the class period was spent in whole-class discussion and student attention was largely focused on the front of the classroom. This also means that while Teacher M may have instructed her students to work individually or in small groups a similar number of times as Teacher C and Teacher B, she did allow or direct her students to continue working individually or in small groups for the same length of time that Teacher C and Teacher B did. It is also interesting see that in Teacher G’s classroom, where we observed the highest number of teacher-student discussions we also see the highest number of student-student discussions. While Teacher G did not directly ask her students to work in small groups as often
as other teachers, her students were frequently observed having discussions with other student peers. We also see that, while Teacher B was observed having more teacher-student discussions than Teacher C, in Teacher C’s classroom we see a higher incidence of student-student discussions.

5.2.5 Math Instruction

Each time a teacher addressed the entire class with information about a particular mathematical concept the occurrence was recorded using the “Math Instruction” code. (A full description of the initial coding scheme is in Appendix A.) The “Math Instruction code was not used when teachers discussed features of the SimCalc MathWorlds technology or what problems in the workbook students should be working on. Rather, the Math Instruction code was used to record when teachers discussed particular ideas in mathematics, such as features of a coordinate plane, how to algebraically represent a rate, or the meaning of positive slope. The following table (Table 25) shows the average, minimum, and maximum number of times each of the teachers addressed the entire class with information about a particular mathematics concept.

Table 25. Average, Minimum, and Maximum observed instances of Teacher Math Instruction

<table>
<thead>
<tr>
<th>Teacher</th>
<th>Total # of Observed Days</th>
<th>Average observed Math Instruction</th>
<th>Minimum (in one day)</th>
<th>Maximum (in one day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>M</td>
<td>4</td>
<td>5.75</td>
<td>3</td>
<td>11</td>
</tr>
<tr>
<td>C</td>
<td>7</td>
<td>2.43</td>
<td>0</td>
<td>6</td>
</tr>
<tr>
<td>B</td>
<td>7</td>
<td>2.71</td>
<td>1</td>
<td>4</td>
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<tr>
<td>G</td>
<td>11</td>
<td>1.82</td>
<td>0</td>
<td>7</td>
</tr>
</tbody>
</table>

We see from the table above that there was a fairly broad range to the number of observed instances of teacher math instruction. In particular, we see that Teacher M, on average, engaged in math instruction more frequently than the other teachers. In one particular class period, Teacher M engaged in mathematics instruction eleven times. However, the other three teachers initiated math instruction less frequently. In particular, both Teacher C and Teacher G had class periods where they were not observed to initiate math instruction at all. Also, Teacher B initiated math instruction from one to a maximum of four times in the observed class periods.

The infrequency of teacher initiated math instruction is surprising. In mathematics classrooms we would expect that teacher math instruction would be a large component of classroom practice. However, the structure of most of the classes appears driven by the teacher and student joint focus on filling out the workbook. The teacher would sometimes bring the activity of filling out the workbook back to the underlying mathematics, often times as part of a review of work that was previously done. However, in some class periods the teachers only discuss what is in the workbook and what the students should be working on.

5.3 Chapter summary

This chapter reports on and describes the findings from the classroom observations and initial coding analysis. In using the SimCalc resources and guiding their students through the SimCalc activities we see that the teachers in this study were acting within different environments with
varying types and set-ups of resources. For Teacher G, the only computing resources available for student use were contained in a single computer lab on campus. Teacher B and Teacher C’s school had multiple computer labs and multiple mobile laptop carts, and they were assigned by their principal to use the mobile-laptop carts. Teacher M reported that there were a number of computing resources on her campus, some of which she procured herself through a resource grant. However, Teacher M made the decision to not make use of those computer resources, and instead used a single laptop and projector in her classroom.

The teachers also had different roles and relationships to the school environment they found themselves in. For example, Teacher G was the only mathematics teacher on her campus and reported a significant amount of autonomy when it came to making decisions regarding her instruction and the resources she used. Teacher M also reported that she had a fair degree of autonomy when it came to instructional decisions despite having new principals in both year one and year two of the SimCalc study. Teacher C and Teacher B, on the other hand, reported a high-degree of involvement and oversight on the part of their administrators. They were even required to create, conduct, and report on self-evaluations of teaching strategies to their colleagues and administrators.

When we look beyond the school environment and physical set-up of the computing resources, we see that the teachers also made different instructional decisions and presented the SimCalc materials in a variety of different ways. Teacher C and Teacher B decided to teach a pre-unit before beginning SimCalc instruction and did not complete the entire SimCalc unit. Teacher G and Teacher M, on the other hand, both decided to teach the majority of the SimCalc unit. We also see that Teacher M decided to teach her class where student focus was largely directed towards her and the front of the classroom, while Teacher C, Teacher B, and Teacher G, employed varying degrees of whole-class discussion and small group work. All of the observed teachers presented SimCalc MathWorlds simulations in a variety of different ways, from expressly directing the students to run the simulation a specific number of times to expecting students to determine when and how they should run the simulation themselves.

From the observations and initial coding analysis we also have a variety of data on student behaviors within these classrooms. We see a variety of student action and interaction with regards to the physical resources available to them, their peers, and their teacher. With both the technological resource and the workbook resource we see a wide range of student-initiated use. In Teacher C and Teacher B’s classroom we can imagine that an individual student’s partner could affect their use of the technological resource, and that some variation in technology resource use in those classrooms could be tied to the student-pair relationships. However we still see a wide range of individual student use of the technological resource in Teacher G’s classroom, and furthermore, we see a wide range of student-initiated workbook use in all of the classrooms. This finding suggests that there are a number of factors, yet unseen, that could influence when and how students make use of and manage the physical resources present.

When we look at the frequency in which students engaged in small group discussions with their peers and teacher we see some relationships to the teacher’s management of the classroom and instructional decisions. For instance, in Teacher M’s classroom, students rarely engaged in teacher-student and student-student discussions. This is largely due to the infrequency with
which Teacher M deterred from a mode of whole-class discussion. In the other three classrooms we see a higher frequency of both teacher-student and student-student initiated discussion, which is largely due to the frequency in which those teachers allowed students to work in small groups and would visit the groups as they worked. However, the teacher instructional decisions do not account for all of the variation in teacher-student and student-student discussion. Teacher C and Teacher B had similar classroom set-ups, employed similar teaching strategies and had a similar number of recorded student-student discussions. However Teacher B initiated roughly twice as many teacher-student discussions than Teacher C. Also, Teacher G, who also allowed students to work in small groups and would circle through the classroom, had roughly twice as many recorded student-student discussions as Teacher C and Teacher B. It is unclear why there were more observed teacher-student and student-student initiated discussions in Teacher G’s classroom than any other classroom.

In the next chapter I will discuss specific instances of learning resource enactments in each of the case-study classrooms. That is, I will describe moments when resources were arranged, allocated, modified, moved, attended to, interpreted, and assigned value to. These instances of learning resource enactment were uncovered after the data was analyzed through a second coding process that focused on documenting the teacher direction of attention and resource use, as well as student use and interaction with resources and peers. These descriptions of learning resource enactment shed light on how, when, and why teachers and students made use of the physical resources, and what roles those resources played in teacher-student and student-student interactions.
6 Constellations of behavior surrounding learning resource enactments

In all four classrooms, the teachers and students were acting within a socio-physical space in which resources were present and accessible in a variety of ways. Throughout the course of the SimCalc unit, the teachers and students established practices, or socio-technical norms, for interacting with one another and negotiating the use and access of resources. That is, the teachers and students established practices that shaped the nature of how and when resources were enacted as learning resources. In the secondary coding, I identified all the moments in which learning resources were enacted, that is, when they were arranged, allocated, modified, moved, attended to, interpreted, and given value to in terms of the social or moral order of the classroom. The following sections describe five themes, in the Grounded Theory sense, that represent constellations of student and teacher behaviors surrounding the moments in which learning resources were enacted. These themes outline how the enactment of learning resources entailed the creation of socially constructed processes that influenced the following: student roles and responsibilities, students’ physical proximity and orientation towards resources, how student attention was managed by teachers and students, how student misunderstandings were addressed by teachers and students, and the social framing of student resource use. While all of the classrooms engaged in the construction of social norms surrounding the access and use of learning resources, the particulars of these behaviors and enactments differed.

6.1 Arrangement and allocation of resources and student roles and responsibilities

The goal of the current project was to describe and report on classrooms that utilized a variety of different technological-resource arrangements. However, the distribution and allocation of other classroom resources also varied across the classrooms. Resources such as overhead transparency projectors, the SimCalc student workbooks, rulers, colored pencils, calculators, and even students themselves were arranged and distributed across the classrooms in different ways. The distribution of these resources impacted when and how students gained access to them.

In this study, it was observed that the students were assigned to particular seating arrangements in response to necessary or unadjustable arrangements of physical resources and in response to teacher pedagogical beliefs. For example, in Teacher G’s computer lab the layout and arrangement of student seating was unadjustable due to the set-up of the computers. However, Teacher G told students upon entering the computer lab that they had to sit alternating “boy-girl-boy-girl”. Teacher G believed that this type seating assignment mitigated some possible behavior problems. In Teacher C and Teacher B’s classrooms, there were not enough laptops for each student to have their own, so students had to be grouped in pairs. However, from post-observation interviews and post-unit phone interviews we see that the seating arrangement of students was also related to Teacher C and Teacher B’s pedagogical beliefs. Teacher C’s students typically sat in individual assigned seats arranged into rows, and she only arranged the student seats into pairs to compensate for the limited number of available laptops. In contrast, Teacher B reported that she always had her students arranged in pairs, and furthermore, she felt the paired student seating structure allowed students to discuss their work with peers more easily.
The arrangement of resources in the classroom spaces, necessitated by the physical properties of the room and teacher beliefs in turn, also influenced how students gained access to them. When we look at the distribution of laptop resources in Teacher C and Teacher B’s classrooms we see an interesting phenomenon related to both the arrangement of the student seats and the number of available laptops. In Teacher C’s class there were a few more laptops than student pairs. Once every pair of students had at least one laptop Teacher C would tell her students that there were extra and that they were free to get their own if they wanted. The extra laptops were allocated on a first-come-first-serve basis, and indeed, the male students filmed with the student focus camera were observed to have their own individual laptops in three (out of seven) of the observed class periods. However, In Teacher B’s class there was only enough laptops for every pair of students to have exactly one laptop. This meant that students in Teacher B’s classroom did not have the option of obtaining “more” of the laptop resource.

The arrangement and allocation of resources in the classroom space also shaped what could be termed “student roles”. For instance, in Teacher C’s classroom, she was observed to tell her students to “switch drivers”. This meant that Teacher C wanted her students to trade-off using the laptop resource with their partner. The term “driver” was used to denote the role of the students directly touching and interacting with the laptop resource. Interestingly, Teacher B was never observed to issue a similar request to her students. Thus, two ostensibly similar classrooms ended up with different learning resource enactments.

Another example of student roles relating to resource allocation can be seen in Teacher M’s class. In Teacher M’s class, a few calculators (roughly five) were distributed to some students in the class at the beginning of each class period. Teacher M would refer to these students as her “calculators”, “multipliers”, or “dividers”. Throughout her instruction, Teacher M was observed to and say things like “where are my calculators? Calculate this speed for us, please.” The term “calculators” was used to denote the student role of students equipped with a calculator resource at the beginning of class. When asked, these students would perform the requested calculations and call out the answers to Teacher M and the rest of the class. Students who were not “calculators” would simply wait until the answer was called out.

An even more interesting student role in Teacher M’s class would be that of the male student who was in charge of running the SimCalc MathWorlds software throughout the unit. This student was in charge of accomplishing and demonstrating all of the tasks or activities that required use of SimCalc MathWorlds. Unlike “drivers” and “calculators” there was no term used by Teacher M and her students to denote this particular student’s role. The following transcript is an example of how Teacher M would ask this student (who’s anonymized pseudonym is “Travis”) to make an adjustment to a SimCalc MathWorlds simulation. In the transcript, Teacher M starts by reading aloud a question from the student workbook and then leads her class through the activity.

[00:13:44.17] Teacher M: "'Make a line that shows Nola won the race.' Okay. So how could she win the race?"
[00:13:50.04] Margie (female student): "She doesn't"
[00:13:54.00] Greg (male student): "He's got to move the line"
[00:13:56.00] Teacher: "We have him move the line, don't we? Very good. How are we going to move the line? Travis?" (Teacher calls on the male student running the laptop, “Travis”)
---(Travis moves the line on the SimCalc simulation to have Nola win the race in 6 seconds.)---
[00:14:00.26] Teacher: "Oh look what he's doing! Look what he's doing? Oh yes, now, see do you think it is possible to run an 100 meter race in six seconds?"
[00:14:19.21] Multiple students say: "No"
[00:14:24.21] Clara (female student): "Maybe in ten seconds?"
---(Travis moves the line on the SimCalc simulation to have Nola win the race in 10 seconds.)---
[00:14:33.25] Teacher: "See he's showing off now, that’s good. He's learning all those little clicks. That's excellent."
-- Transcript from video 25211_91906_Cam2

While only one male student was in charge of the laptop and SimCalc MathWorlds, all of the students were called up to fill in questions on the overhead transparency projector at least once. In her second-year post-unit phone interview, Teacher M described these student responsibilities and how the student running the computer would take directions from her and other students.

INTERVIEWEE: “Yeah they wrote down in their workbook but on the overhead each child, they would take turns sitting up there with overhead and they had the page and you know like say page 8 and they had questions, ‘what is the average speed of a black ant’ or something. They would write down their answers that they came up with together. They would discuss it and then they would decide and then they would write it down for everybody more or less at the same time.”
INTERVIEWER: “Okay. So you had one particular student writing on the overhead?”
INTERVIEWEE: “Every child had a chance at it.”
INTERVIEWER: “Okay so you traded off there. What about running the computer?”
INTERVIEWEE: “A different child.”
INTERVIEWER: “You had one computer that was projected in the front of the class and then you had one student operating that computer? I don’t want to put words in your mouth.”
INTERVIEWEE: “That’s right. And then I had a student at the overhead where I made transparencies of each page and everybody was guiding. So they would know exactly where they were at. And then we did the class discussion for a question and they wrote down the conclusion that we decided.”
INTERVIEWER: “And how did the student control who was controlling the computer? How were they guided?”
INTERVIEWEE: “I guided them.”
INTERVIEWER: “Yeah so you told them what?”
INTERVIEWEE: “Well they read the question and say okay open this file and they would open the file and he would enlarge and do whatever the kids wanted to see. If they wanted to see it run again, he would redo it, you know reset it and run it again. It was totally awesome for the kids. The experience was unique.”
– Teacher M post-unit interview, Year Two
While the observed classrooms were chosen for observation based on the limitations and arrangement of computing resources, similar limitations and arrangements of the classroom space can be seen with regard to other physical resources. For example, all four of the classrooms I observed had boxes of colored pencils and rulers. However, in Teacher B and Teacher M’s classrooms it was the responsibility of the student to obtain or request these resources when needed (that is, Teacher B and Teacher M are never observed to distribute these resources without first having been requested to do so by a student). In contrast, Teacher G and Teacher C were both observed to hand out or instruct other students to distribute the resources to the students when workbook activities required it.

The student workbooks in particular were a physical resource that all students had individual access to during the course of a class period, but the responsibility for maintaining and storing the workbooks was different across the classrooms. Teacher C, Teacher B, and Teacher M allowed their students to take the workbooks home with them. However, Teacher G collected the workbooks at the end of every period. Even when Teacher G assigned homework from the student-workbook, she would make copies of the assigned pages for students to take home. In Teacher C, Teacher B, and Teacher M’s classrooms it was the students’ responsibility to maintain and remember their student workbooks. In Teacher G’s classroom it was the teacher’s responsibility to maintain the workbook resources. This suggests that the role that could be termed “ownership”, or the social role associated with responsibility in maintaining the workbook resource, differed across the classrooms. In some classrooms the teacher “owned” the workbook resource (Teacher G) while in others the students owned the workbook resource (Teacher C, Teacher B, and Teacher M).

6.2 Modification and movement of resources and student orientation and physical proximity to resources

While resources were arranged in certain ways throughout the classroom space and allocated to certain actors, the resources were often moved, rearranged, reallocated, and even sometimes modified throughout the course of the classroom observations. Both teachers and students were observed to move resources as they went about the task of conducting and working through classroom activities, furthermore, these modifications to and movements of classroom resources affected student orientation and physical proximity to resources.

6.2.1 Teacher resource modification and movement

Teacher C and Teacher B made modifications to the SimCalc unit lesson plans and activities prior to being observed. Teacher C and Teacher B taught what they referred to as a “pre-unit” on rate and proportionality before their students were even introduced to the SimCalc materials. In post-unit phone interviews, Teacher C and Teacher B described the pre-unit as more “traditional” proportionality and problems similar to what the students will see on TAKS exams. Throughout the course of teaching the SimCalc unit Teacher C and Teacher B made what could also be considered modifications to the SimCalc materials in that they introduced new worksheets they created themselves and sometimes reordered, skipped, or altered the objectives of particular problems in the student workbook.
For one particular lesson, called “On The Road”, Teacher C altered the instructions of the workbook activities by telling her students to not run any of the associated simulation files, or even retrieve a laptop for their group, until they had finished sketching graphs for all of the problems in the lesson. (The original instructions ask students to watch the simulations for each individual problem.) This meant that for the first 43 minutes of the class period the students did not have access to the laptops or SimCalc MathWorlds. They only retrieved the laptops and made use of SimCalc MathWorlds after they had completed the lesson. This meant that the SimCalc MathWorlds simulation was used as a means of checking whether the students’ interpretations of the road trip stories were correct, rather than an additional resource for formulating interpretations of the road trip stories.

Teacher G, for the most part, followed the SimCalc lesson plan and worked through the SimCalc activities with her students as they had been designed. However she also modified the SimCalc student workbook resource. Teacher G had her students take a page of notes on the back of their workbooks before starting the SimCalc unit. The notes consisted of definitions and examples of terms they would see throughout the unit such as “ratio”, “proportion”, and “rate”. While Teacher G’s class was working through the SimCalc unit she would refer to these notes as “what’s on the back of the workbook”. If her students seemed to be stuck on a particular problem she would sometimes help them by directing them to review what they had written on the back of their workbooks. This meant that the student workbook was framed as a source of reference as well as a source of classroom activities.

Teachers were also observed to move and rearrange themselves, their students, and other resources throughout the course of a class period. Teacher C and Teacher B were both observed to rearrange and reallocate resources based on what they saw as student behavior problems. Teacher C would move students to different desks to sit by themselves when she felt that they were not focusing on the task at hand and were distracted by their partner. In one class period, Teacher B asked her students to retrieve laptops for their group then almost immediately after all the students were seated again told her students to close and put the laptops away because they were talking too much. Teacher G was observed to rearrange her classroom space to further a pedagogical goal. When teaching from her usual classroom, Teacher G would sometimes divide her students into small groups and have them rearrange their desks so they could face their group members. The following transcript is an example of Teacher G dividing her students into groups and then presenting a SimCalc simulation.

[00:59:59.22] Teacher: "Turn the page, to page 6. These two pages are some things you are going to do in a little group. " (Teacher starts at the far right of the room and moves to the left, pointing to students and assigning them to small student groups of three students each.)
[01:00:26.00] Teacher: "Do it right now, I'm going to give you 30 seconds to arrange your desks into groups. Go."
[01:00:29.01] (All of the students move their desks into their groups, while teacher counts down from 30.)
[01:01:06.09] Teacher: "… five, four, three, two, one. Okay. In your groups. I'm going to go play, another simulation on the computer, and then in your groups do what those things tell you to do.”
Teacher: "what's the file?" (Teacher walks over to the computer on the teacher desk.)

Multiple students: "Another One dot ‘M’ ‘W’ "

Teacher: "Here we go" (Teacher plays the simulation once.)

(Teacher runs the simulation again.)

Teacher: "Eyes on the TV screen. Mouth closed. See? Here we go"

(A male student wearing a green shirt points at the TV screen.
There is some student talking – unable to transcribe.)

Teacher: "One more time"  (Teacher runs the simulation for a fourth time.)

-- Transcript from video 28411_102406_Cam2

For this particular workbook activity, Teacher G instructed her students to work through a series of workbook problems in their small groups. We see in the transcript above that she asked students to rearrange their desks to facilitate group work. By rearranging students into groups, Teacher G is enabling and encouraging her students to access or enact their peers as learning resources. We also see that one male student after moving his desk closer to his group-mates gets up from his seat to stand closer to the TV while the simulation is being displayed. In this scenario, the student is unable to enact the simulation as a learning resource unless he physically moves himself closer to it. This suggests that orientation and proximity are key physical factors in how learning resources are enacted.

6.2.2 Student resource modification and movement

As demonstrated in the transcript above, students would also move and rearrange themselves in the classroom space. Students in Teacher G’s classroom would sometimes stand up and move closer to the TV in order to see it better, and two students in Teacher M’s classroom would frequently move their desks closer to the front of the classroom.

Students in all of the observation classrooms were observed frequently sharing resources, such as colored pencils and rulers. In the case of Teacher B and Teacher C’s classrooms the students also shared the laptop resource. All of these physical resources were frequently rearranged and reallocated among the students and student groups as they progressed through classroom activities. This does not mean that sharing resources was necessarily easy or without conflict for the students.
The two female students filmed with the student focus camera in Teacher B’s classroom, did not make equitable use of the laptop resource throughout the observations as measured by the number of times each student initiated technology use (recorded via the “Technology Student Initiated” code). Over the course of the seven class meetings, the student on the left (Student A), on average, initiated laptop use 8 times in each class period, whereas her partner (Student B) initiated use on average 5 times. In one class period in particular, Student A initiated technology use 13 times and 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 16. Student A did not orientate the laptop towards herself in one broad gesture; instead, she moved the laptop gradually moved over 27 minutes.

When we focus our attention on Student A and B’s exchanges during this time, we not only find apparent inequity in how the two students shared the laptop, but also in how they shared other classroom resources. The following transcript shows ongoing negotiations about another shared resource, colored pencils, over a three-minute time span.

[00:16:18.29] (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 colored pencil.)
[00:16:23.07] (A puts down the brown colored pencil and reaches for the green colored pencil in B’s hand. She takes the green colored pencil, and B picks up the brown colored pencil. Both begin writing in their workbooks.)
[00:16:40.22] B: "can I borrow your green one more time?"
[00:16:43.15] A: "no"
[00:16:47.03] (B rests her head in her hand. She is not writing in her workbook, but is holding the brown colored pencil.)
[00:16:49.27] (A puts the green colored pencil down on the desk and reaches for the brown pencil in B's hand. B picks up the green colored pencil.)
[00:16:52.12] B: "thank you"
--- (Both students write in workbooks) ---
[00:17:15.10] B: "here is your stupid green back." (B hands the green colored pencil to A.)
[00:17:20.14] A: "you are calling my green stupid."
[00:17:21.25] B: "no I wasn't, I was saying cupid."
[00:17:25.25] A: "I'm not stupid."
[00:17:28.17] 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)
[00:17:42.20] B lunges toward the colored pencils again. She takes the brown colored pencil.
[00:17:45.24] B: "Ha Ha Ha. I got it."
[00:17:47.15] A: "Not cool."
...(Students both write in workbook)
[00:18:38.07] B: "can I borrow your green?"
[00:18:39.07] A: "no"
[00:18:41.21] (B stands up and walks away.)
[00:19:11.00] (B returns to her desk with another green colored pencil.)
[00:19:12.00] (A reaches over and takes a ruler off B's desk.)
-- Transcript from video 27913_120406_Cam2

This interaction suggests that sharing resources in these circumstances and for this pair engenders conflict. 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.

The turning of the computer suggests that the computer is part of on-going contention. Unlike the pencil, more cannot be obtained, at least in the short run, and over a period of seven days of instruction, we see consistent inequity and contention. Across the seven class meetings, Student A, on the average, initiated laptop use 8 times in each class period, whereas Student B initiated use only 5 times.
When we examine how often the students visible in the student-focus camera placed in Teacher C’s classroom shared the laptop resource, we see a more equitable use of the technology. Over the course of our observations, student ‘C’ (circled in the diagram above) initiated technology use roughly 8 times a class period, and similarly student ‘D’ initiated technology on average 9 times. Also, when we focus our attention on their day-to-day behaviors regarding other classroom resources, we see examples of seamless resource exchanges, as well as productive dialog. This is illustrated in the transcript below, outlining student C and D’s behavior while they complete a SimCalc activity. In the activity, they are asked to watch a SimCalc MathWorlds simulation, involving a ‘bus’ and ‘van’ road-trip, and to draw a corresponding graph in their workbooks. At the start of the road-trip the van is traveling at 60 mph then speeds up to 62 mph. This is a point of brief confusion for Student D, which is resolved easily by his partner, Student C.

[00:50:15.00] (C and D are both writing in their workbooks.)
[00:50:16.05] (D puts a red colored pencil on C’s desk. When C has finished writing he looks up. D takes a blue colored pencil out of C’s hand. C picks up the red colored pencil on his desk. Both write in their workbooks.)
[00:50:27.21] (C finishes writing, and looks up towards the front of the class. D puts the blue colored pencil on C’s desk, and takes the red colored pencil from C’s hand. D goes back to writing in his workbook. C continues to look towards the front of the class.)
[00:50:31.29] (D leans over the laptop and points to a graph drawn in C’s workbook. C looks to what D is pointing at.)
[00:50:34.12] D: "isn't this one farther up?" (D motions to the laptop screen, and back to a line draw on C’s graph.)
[00:50:37.16] (C shakes his head [no].) C: "its going 60."
[00:50:41.25] D: "and then he goes 62." (D motions again to the SimCalc MathWorlds simulation on the laptop.)
[00:50:42.10] C: "yup" (C points to a point on the graph he has drawn in his workbook.)
[00:50:46.11] (D looks at where C is pointing, nods, and writes in his workbook.)

-- Transcript from video 27912_120106_Cam2

In this interaction we see the seamless, and wordless exchange of resources (colored pencils), as well as constructive dialog about the activity at hand. When D wants to exchange colored pencils
with C, he simply places the colored pencil he has on C’s desk, and waits for the other pencil to become available (as indicated by student C, looking up from his workbook). Student C does not hinder Student D’s acquisition of resources, and C even seems to present himself and his workbook as an available resource to D by answering D’s questions and allowing D to view his workbook.

6.3 Attention to resources and attention management

Attention management was an important task or role for teachers and students across all four of the observed classrooms. Teachers often sought to assess, direct, and redirect student attention to important learning resources and particular facets of learning resources. Students would also assess and redirect their teacher and peer’s attention, as well as their own. The following two sections describe the ways teachers and students would assess and redirect the attention of other actors in the classroom space. We see from examples of teacher and student attention management actions that they would redirect students’ attention for three possible purposes: establish what the current task is, provide an aid to understanding, or maintain a common focal point for collaboration.

6.3.1 Teachers managing student attention

When we enumerate the number of physical learning resources that students had access to in the four observed classrooms we can see that the SimCalc intervention provided two: student workbooks and the SimCalc MathWorlds software. (The SimCalc intervention provided other learning resources, such as teacher professional development and the teacher workbook/lesson plan, but these were not physical resources that the students had direct access to.) Teachers across all four classrooms were observed to frequently direct students to specific page numbers and problem numbers in the student workbook. This direction of student attention was most commonly observed at the start of class periods, but it was not uncommon for teachers to direct student attention to particular problems in the workbook throughout the class period in whole-class and teacher-student discussions. Often times these directions could be viewed as teachers directing students’ attention to what the current task is.

In the following transcript, Teacher M directs student attention to the next problem they are working on in the student workbook (problem ‘B’). She then asks a student to read the directions aloud. It was common for Teacher M to follow her directions of attention to a specific workbook problem by then asking a specific student in the class to read instructions aloud.

[00:19:29.10] Teacher: "Okay you all, we're on 'B'. Greg, you're mouth is open so why don't you read it to me."
[00:19:34.10] Greg (male student): "Okay. ‘Now run the simulation. How far ahead of Max was Nola when she crossed the finish line?’” (Greg reads the instructions to problem 1:b, p. 12 in the student workbook aloud.)

-- Transcript from video 25211_91906_Cam2

Teachers would also direct student attention to particular physical resources as an aid to understanding the classroom task. For instance, in multiple class sessions Teacher G was observed to instruct her students to “watch the graph at the same time.” Directing students to watch the graph while simultaneously watching the simulation was a way Teacher G would
direct their attention to the relationship between the simulation movement and the corresponding graph. Teacher C would also direct her students’ attention to particular aspects of the SimCalc MathWorlds simulations. The following transcript is an example of Teacher C directing her students’ attention to a particular functionality of the SimCalc MathWorlds software.

[00:36:45.21] Teacher: “What else did you see on this one?”
[00:36:47.21] Teacher: “Because lots of you were using the step button.”
[00:36:52.04] Male Student: “Oh”
[00:36:53.27] Teacher: “What do you think? What are some things that we could add?”
[00:36:57.22] Male Student: “Oh um Kim, he went 5 meters per second. Like at meter 5 it would be 1 second.”
[00:37:09.20] Teacher: “Okay, wait, say that again.”
[00:37:12.16] Male Student: “When you hit the step button, he goes 5 every....like he's on the line by fives every time.”

--Transcript from video 27912_112706_Cam2

The transcript above is an example of Teacher C directing student attention to the step-function in the SimCalc MathWorlds software. By using the step-function, which moves the simulation forward by one time segment at a time, the students can easily determine how far a particular runner goes every second. Teacher C directs student attention to this SimCalc MathWorlds functionality to help her students notice and observe something in the simulation and graph, namely that one of the runners is going five meters per second. By directing student attention to a particular functionality in SimCalc MathWorlds, Teacher C hoped to help her students better understand the simulation and graph.

Teachers would often instruct students to turn their attention away from one resource (such as the laptop or computers) and instead focus on another (such as the teacher). When teaching from her classroom space, Teacher G frequently told her students, “Mouth closed, eyes on the TV.” This meant that she did not want her students to talk with one another or to her, but rather focus their attention on the projected simulation. In the computer lab space, Teacher G would also direct students’ attention when she would say, “Where should your hands be right now?” This meant that she wanted her students to redirect their attention to her as she engaged in whole-class discussion. Similarly, Teacher C would say “hands off” to her students while she was engaged in whole-class discussion, and in one class period she told her students to “fold the top part of the laptop down and look at me”. This meant that she wanted them to focus their attention on her as opposed to the technology.

The student workbook, the SimCalc MathWorlds simulations, the teacher, and the students could all be considered important learning resources that students would focus their attention on throughout any classroom period. The teachers in our study were observed to verbally direct and redirect student attention to and from these resources. Sometimes these directions could be conceptualized as informing students “what the current task is” and at other times the directions could be conceptualized as giving students “aid to understanding” the classroom task or mathematics.
6.3.2 Students managing teacher and student attention

Students in all four classrooms were also observed to actively direct and redirect their own attention, their peers’ attention, and their teacher’s attention to resources. The most common type of student management of attention, observed across all four classrooms, were students asking or telling peers what page and/or problem they were on in the workbook. This type of attention management could be conceptualized as communicating “what the classroom task is”.

When students sought the attention of their teachers they could either be seeking to redirect their own attention to “what the classroom task is” or seeking an “aid to understanding” the current classroom task or problem. A common way for students to gain the attention of their teacher was to raise their hands and say their teacher’s name. However, sometimes students did more to gain their teacher’s attention. For example, when Teacher G taught from the computer lab, she would often walk around the student seats and answer student questions. When her students needed her help they would first raise their hand and say her name. However in one class period, Teacher G’s students were observed to stand up and walk over to Teacher G, wherever she was standing, and wait for her attention.

![Diagram of Teacher G's classroom with students filmed with student-focus camera labeled as “E”, “F”, “G” (light gray indicates female student, dark gray indicates male student)](image)

Figure 18. Diagram of Teacher G's classroom with students filmed with student-focus camera labeled as “E”, “F”, “G” (light gray indicates female student, dark gray indicates male student)

Also, students in all four classrooms were observed to direct their peers’ attention to specific aspects of the physical learning resources available to them. This direction and redirection of a peer’s attention most commonly occurred when students were collaborating. Students would direct a peer’s attention to the SimCalc MathWorlds simulations by either silently pointing and motioning to the computer screen or verbally directing. Students would also direct a peer’s attention to the workbook resource in a similar manner. These student redirections of student attention occurred when students needed to establish what the current task is, provide an aid to understanding, or, for students working together in groups, to establish a common focal point for collaboration.
The following figure (Figure 19) and transcript depicts three students in Teacher G’s classroom who were assigned to work in a group together. The three students are collaborating on a series of workbook problems. Since in the computer lab space the students cannot rearrange their desks to face one another they have to work out other ways to establish focal points for collaboration and communicate across the group. For this particular group, Student F who sits in the middle is observed to turn her attention back and forth from Student E to Student G. Student E and Student G are never observed to directly communicate to one another, but they both frequently communicate with Student F. Throughout the course of their collaborations, we see the three students direct their peers’ attention to the workbook and technological resources.

Figure 19. Pictures of students collaborating on a workbook problem in Teacher G's computer lab

[00:15:16.29] (F is turned facing the student to her right, G. F is holding up her workbook and showing it to G.)
[00:15:19.00] E: "Alright, I'm almost done."
[00:15:19.18] F: "Okay" (F turns back and faces E. She looks at his workbook.)
[00:15:24.01] E: "At four they are at... oh dang" (He uses his pencil eraser, then writes something on the graph in his workbook.)
[00:15:31.23] (F looks at her workbook, then looks back to E’s workbook.)
[00:15:33.12] E: "At four they are both at the same point."
[00:15:35.23] (F turns back to her workbook and puts her pencil (in her right hand) on a point on the graph in her workbook.)
[00:15:39.07] F: "Let me see." (She puts her finger (left hand) on a point the graph in E's workbook. She then turns and draws a point on the graph in her workbook where her pencil was placed.)
[00:15:40.06] E: "Yea look." (E motions to the computer.)
[00:15:42.20] (F looks at E's computer screen, looks at where her pencil is being held on her workbook, then looks at where her finger is on E's workbook.)
[00:15:46.13] F: "Okay." (She takes her pencil off of her own workbook and her finger off of E’s workbook.)

-- Transcript from video 28411_110106_Cam2
In the transcript above we see that Student F first shows her workbook to the student on her right, Student G. When Student F directs Student G’s attention to her workbook she is using her workbook as a physical demonstration aid. This could be conceptualized as Student F using her workbook as an “aid to understanding”. When Student F turns back to discuss a point with Student E, she puts a finger on his workbook and her pencil on hers. She is maintaining her own attention on a particular point in the student workbook while also maintaining Student E’s attention on the same point in his own workbook. This accomplishes the task of “establishing a common focal point” for their collaborations. These students are using each other as learning resources and to accomplish the group task they need to establish focal points for collaboration.

6.4 Interpretation of resources and assessing student understandings

Another important task for teachers and students across the four observed classrooms was assessing and addressing student understandings. Teachers assessed student understandings by spending some amount of their time attending to individual or small student groups and by calling on students to interpret learning resources during instruction. Students would also assess and address their own understandings and the understandings of their peers by referencing and interpreting learning resources.

6.4.1 Teachers assessing and addressing student understandings and resource interpretations

We could argue that one of the primary roles of teachers is to assess and address student misunderstandings as they arise through learning activities. All four teachers in this study were observed to employ a variety of mechanisms to poll or assess student understandings and then correct misunderstandings as they arose. One common method of assessing student understanding for all four teachers was to devote some of their attention to individual or small groups of students. Teacher G, Teacher C, and Teacher B did this by circling around the room while their students worked individually or in groups. By looking over their students shoulders and stopping to discuss what the teacher saw in their student workbooks the teachers were engaged in actively assessing and addressing any student misunderstandings that arose. Teacher M engaged in teacher-student discussion much less frequently than the other three teachers, but she did have three to five students in a class period come up to the transparency projector to work out a workbook problem in front of the class in every class period. Every student in Teacher M’s class did this at least once during the course of the SimCalc unit. In this way, Teacher M was devoting some of her attention to individual students, and when misunderstandings arose she would address them in the context of whole-class discussion.

All four teachers were observed to call on specific students to answer specific questions during whole class discussion. In one particular class lesson with Teacher M, she calls on a particular student in the back of the classroom and tells him he “is looking sleepy.” She then asks him to lead the class through his explanation of a specific workbook problem. The student describes the problem and how he solved it without error. Teacher M responds that she is “impressed” and that the student “gets an ‘A’ for the day.” This interaction suggests that Teacher M looks upon her classroom and may suspect student misunderstanding (or lack of student focus) with specific students. She then addresses this by calling on them individually to interpret learning resources.
Figure 20. Diagram of Teacher M’s classroom with students filmed with student-focus camera labeled as “H”, “I” (light gray indicates female student, dark gray indicates male student)

Teacher G, while presenting from her usual classroom, would also call on specific students throughout the course of whole-class discussion to assess and address their understandings. During one class period, Teacher G calls on a particular student without him having raised his hand or giving any other direct request for attention. (Student names have been anonymized.)

[00:03:49.26] Teacher: “Taylor, do you feel more comfortable with this concept than you did yesterday?”
[00:03:54.20] Taylor: “I think so.”
-- Transcript from video 284_102706_Cam1

Here we have evidence that Teacher G not only monitored this students’ understanding in a single class period but rather the process of assessing and addressing this student’s misunderstandings spanned across multiple class periods.

The teachers in our study were also observed to address misunderstandings by asking students to help one another. Teacher B reported in her post-unit interview that she paired students in her classroom for expressly this purpose. Also, both Teacher M and Teacher G were observed to directly ask students to help one another. In the last observation session conducted from Teacher G’s classroom, Teacher G is tells one female student, who Teacher G believes understands the concept being taught, to help another male student, who has told Teacher G that he doesn’t understand.
The female student sits directly in front of the male student. Throughout the rest of the class period the female student completes what she needs to do in her own student workbook and then turns around in her seat to look at what the student behind her, the student she was asked by Teacher G to help, has done in his own workbook. The female student is also observed to pick up her workbook and place it on the desk behind her for the male student to see. While these two students interact with one another Teacher G circles through the classroom helping individual students. Teachers can capitalize on the student understanding they have already established by asking those students to help and address the misunderstandings of their peers.

6.4.2 Students assessing and addressing student understandings and interpretations

Students also engaged in assessing and addressing their own understandings of learning activities as well as that of their peers. In all four classrooms we observed instances when students asked questions of their teacher for the purposes of addressing a misunderstanding that they have. Also, when we review the video data taken with the student focus cameras, we have observed students in all four classrooms asking their peers for help with a misunderstanding.

The following transcript is an example of a student assessing and addressing his own misunderstanding of a workbook activity by engaging with both his teacher (Teacher M) and then the student sitting next to him. (The students in this transcript are “Student H” and “Student I”, labeled in Figure 20.)

[00:22:52.14] Teacher : "Okay [Student H], what's your prediction?"
[00:22:56.16] (H leans forward, looking at the projected simulation.) H:"115?"
[00:23:00.27] Teacher: "no less, its going to be less than 110"
[00:23:08.08] H: "oh, yea.... 103? 104?"
[00:23:13.01] I whispers to H: "107"
[00:23:15.14] Teacher: "looks like 106 or 107"
[00:23:17.26] (H leans far forward in his seat, trying to look at the projected screen.)
[00:23:19.20] Teacher: "its a little bit past the half"
[00:23:20.25] H: "is it over the 10?"
[00:23:25.04] Teacher: "just a fraction over... Okay, someone give me another number"
(The teacher goes on to discuss another point on the graph with other students in the class.)
[00:23:43.17] H whispers to I: "Was it over the 10 line?"
[00:23:44.27] (I nods.)
[00:23:46.29] H whispers to I: "I thought it was under"
[00:23:48.18] I: "It was under not over."
[00:23:54.16] H: "Oh, but wasn't it.... Oh"
--- (Teacher asks the students to turn the page and go on to the next problem. Student H and Student I turn the page in their workbook with the rest of the students in the class.) --
[00:24:13.29] (H, turns back to the previous page and points at a line in a table in his workbook.) H to I: "What did you put down for that number?"
[00:24:21.29] (I turns the back a page in her workbook, looks at it, and points to spot in the table. I moves her workbook closer to H. H looks at I’s workbook and where she is pointing, then H turns back to his own workbook. I moves her workbook back to where she had it before.)

In the transcript above, we see that Teacher M calls on Student H to answer a question about a SimCalc MathWorlds simulation and graph. Student H has difficulty seeing the graph and cannot determine the correct answer on his own. He then asks the student next to him, Student I, to help him address his misinterpretation of the SimCalc MathWorlds simulation. Student I helps Student H by both explaining what she answered as well as by giving Student H access to her workbook. Student H can then reconcile his misunderstanding after he has interpreted these learning resources.

6.5 Values assigned to resources and framing of resource use

In the post-unit phone interviews the teachers in this study were asked to report on a number of their perceptions and beliefs, including the successes and difficulties they had in teaching rate and proportionality, the appropriateness and usefulness of the SimCalc resources, and the rationale behind instructional decisions they made. We found that teachers in our study told us their perceptions about the SimCalc resources and their students, and sometimes these perceptions were echoed in what we saw in the observation data. The following sections report on teacher perceptions and classroom behaviors that illustrate the ways they framed or conceptualized, appropriate resource use, classroom control, and student sharing and conflict. These discussions show us the values teachers and, in some cases, students associated with particular resources in terms of the moral or social order of the classroom.

6.5.1 Framing of appropriate resource use

Teacher G, who used the computer lab, would frequently ask her students to turn around in their chairs and face her. She would also ask her students to not use the technology at particular points of time, on average, twice a class, as illustrated in the following transcript:

[00:04:07.06] Teacher: "where should your hands be right now?"
[00:04:11.18] Multiple Students: "off the computers"
Teacher: "off the computers, okay. A rate compares quantities through division. See that in the workbook?"

Later in the same class period, we notice evidence suggesting that computer use was something to be noticed and commented upon by students.

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.

Boy says to the girl on his right: "you cheating"

Girl to the left: "what? Its fun. ::mumble:: the simulation. Look."

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.

The boy refers to using MathWorlds in the way anticipated by the designers, that is, by playing simulations over and over, as “cheating”, but the girl says that it’s fun.

More routinely, and observed in multiple class periods, students in Teacher G’s class would ask for permission before running simulations.

Female Student: "Can we run the simulation?"

Teacher: "Yes, you can go ahead and run the simulation for roadtrip1 and be looking at it."

Students are accomplishing the work of learning mathematics in a setting that influences their notions of what constitutes appropriate use of technology and they are having very different experiences. It is probably not good that the boy in Teacher G’s computer puts his head down, as opposed to interacting with the software like his peers to the left and right of him. This could represent a lost learning opportunity. However, when we examine the teachers’ perception of the technology, we see different and conflicting points of view.

When we turn to study teacher’s comments about technology use in their post-unit interviews, we see a range of opinions. Teacher G 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. So sharing that attention with the computer was I guess an adjustment for me." – Teacher G post-unit interview, Year Two

Since the students faced away from her and towards the computers at the perimeter of the classroom, Teacher G found it hard to recognize whether the students were paying attention to her or not.
Teachers B and C, who used traveling laptop carts, saw the issue as one of knowing what the students were doing:

“\textit{You know, when the whole thing started, I was kind of undone that we got the laptop instead of the computer lab because I had really wanted the lab so they could each have their own and I just - you know, you can kind of keep an eye on everyone better when you are in the computer lab because you can just turn and see everyone's computer and what they are doing with it}” – Teacher B, post-unit interview, Year One

"\textit{The only thing with the [computer] labs is that you do get to stand there and see where all of them are doing. I know I found myself walking to the back of the room a lot so I could watch exactly what they were doing because there were lots of giggles from different computers. So when you are in the back of the room, you could see everybody is on the right simulation, it was helpful and I know in the computer lab, that’s very helpful because you are standing in the middle seeing all the screens.}” – Teacher C, post-unit interview, Year Two

To Teacher C and Teacher B, the computer lab scenario had an advantage over their current set-up. In the computer lab the teacher would know what the students were doing with the program. However, to Teacher G, the computer lab set-up made it harder for her to establish and maintain student attention when she needed. In both cases, the teacher’s perception of student behavior with respect to the resources shaped the way they framed appropriate resource use in their classrooms. Different teachers advocated different relationships to the technology, but maintaining control of one kind of another seems central to all.

\textbf{6.5.2 Framing of control}

When Teacher G reflected on her experiences teaching from the computer lab, she reflected on this difficulty she had maintaining control of student attention. When Teacher C and Teacher B reflected on their experiences teacher with mobile-laptop carts, they reflected on the difficulty they had maintaining and monitoring students’ activities on task. Teacher M used only one laptop with a projector. This obviated questions of monitoring and controlling student technology-use, but led to an unexpected characterization of the situation. She felt that her students were in control of the interactions with SimCalc MathWorlds.

"\textit{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, where to look, how to get it. And I said, 'how do I do this?' and they would elaborate on it. And so, they're the ones that were practically teaching themselves. Once they got into it, they were teaching themselves and teaching each other and telling me what to do, which was totally awesome because that's what I wanted. But they had to have guidance - little bit of guidance.}"

-- Teacher M post-unit interview, Year One
“You know I did do the lessons like I did last year as a whole group class and the kids did it all. They wrote on the overhead. I made transparency of each page and the kids wrote down the answers that they collected. And they wrote down their answers and then I had a child on the computer because I projected on the projector and they did it all, every bit of it. I just guided them to where they needed to be. So it was almost like self taught sort of.” – Teacher M, post-unit interview, Year Two

However, Teacher M also discussed how the laptop and projector set-up allowed her to maintain a level of control over the classroom as well.

“That’s the reason why I kept them under control. It was too large and you would lose some of them. Some of them would never get it. In this way I made sure everybody was together and no child was left behind.” – Teacher M post unit interview, Year Two

To Teacher M, it was important for students to maintain a level of “control” over classroom events. She also clearly valued the model of a classroom where students are “teaching themselves” and the teacher has the role of “guiding” them. However, Teacher M was also concerned with the logistics of keeping the students “together” and making sure no one fell behind. Teacher M’s views are shadowed in her observed classroom set-up and instruction.

6.5.3 Teacher framing and perception of student sharing

When we turn to interviews conducted with Teacher B, we see that she puts a priority on grouping her students into pairs, whether using technology or not. 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 because I think they have a lot more dialogue about what's going on. I would do that either way. And 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 and talking about how they did it and why it worked that way.” – Teacher B

However when we look at the interviews conducted with, Teacher C, in the same school as Teacher B and also using mobile laptop-labs, we see that she does not put the same value in having the students paired together. Usually her classroom is arranged into individual rows, and Teacher C only paired her students while she taught the SimCalc unit to handle a specific resource limitation, the limited number of available laptops. Also, she expressed worry that some students would overly depend on their partner to complete the work.

“…for those that want to slide under the gun, they were able to because their partner was able to answer the questions or help them through it.” – Teacher C

When we asked Teacher C if she had any teaching strategies to handle this, she said she would often tell the students to “take turns” with the laptops. Indeed, throughout the observations Teacher C would frequently ask her students to “switch over” or “switch drivers” when they were using the laptops.
Both Teacher B and C operated within the same school, had nearly identical sets of resources, had similar classroom set-ups, and collaborated frequently. However, we see strikingly different examples of student collaboration and sharing in their classrooms. These observations suggest that resource sharing can either be a point of contention for students, or a constructive experience. For either case, we see that the nature of resource sharing as a factor that may interact with conditions of success for SimCalc use.

Also, when we turn to Teacher C and Teacher B’s interviews and their perceptions of student interactions we see two different views. For Teacher B, the student pairing is a feature of the classroom set-up. For Teacher C, the student pairing is an instructional concern. Both teachers acted on their perceptions of student pairing, which potentially had impact on the framing of student interactions in those classrooms.

6.6 Chapter Summary

In all four classrooms, the teachers and students were acting within a socio-physical space in which resources were present in a variety of forms. Throughout the course of the SimCalc unit, the teachers and students established classroom practices for interacting with one another and negotiating the use and access to the resources present. Both the teachers and students were active participants in the creation of these practices or norms. In this chapter I have identified five emergent themes that represent important constellations or systems of behavior norms surrounding the use of resources. All of the themes represent ways and “whys” that both teachers and students arranged, allocated, modified, moved, attended to, interpreted, and assigned value to resources in the classroom space.

In this study we have seen that student seating, as well as the allocation of moveable physical resources (such as laptops and calculators), was driven by physical limitations of resources and teacher classroom management decisions. Teacher G could not alter the arrangement or set-up of the school computer lab, which influenced the possible arrangements of students. However, Teacher G chose to have her students sit alternating boy-girl-boy-girl because she believed that arrangement mitigated some student behavior problems. Teacher C and Teacher B could not increase the number of laptops available in their classroom and had to arrange their classroom spaces such that students could share. However, Teacher B viewed the arrangement of students into pairs as a feature of the classroom space, enabling more student peer discussion, and Teacher C saw the arrangement of students into pairs as a classroom management concern. These views shaped how Teacher B and Teacher C normally arranged their classrooms: student pairing was the norm in Teacher B’s classroom, while student pairing was a deviation from the norm in Teacher C’s classroom. Teacher M only had one laptop and a projector in her classroom, but she chose that physical resource arrangement over the arrangement of her school’s computer lab due to classroom management concerns. She felt it was more important to make sure that her students were “together” and “no child was left behind” as they progressed through the SimCalc unit. The arrangement of students and allocation of resources across the classroom space affected both student access to resources and what we see as student roles and responsibilities.

Throughout the course of the observations we saw that resources were modified and moved by teachers and students. Teacher C, Teacher B, and Teacher G made modifications to the SimCalc lesson plan and/or student workbook activities before and during the course of teaching the
SimCalc unit. The teachers would also move students and physical resources to facilitate classroom tasks, such as student group work, and as a strategy to deal with student behavior issues. When we look at the observed student behaviors we also see that they would move and rearrange resources in the classroom space. Students would move themselves and other physical resources to gain access or to grant access to other students. Student sharing of resources was common, but not necessarily a process free of conflict. The modification and movement of resources represents changes in student proximity and orientation towards resources, and this influenced how students used and accessed learning resources.

Teachers and students were both observed to actively direct and redirect student attention to resources arranged across the classroom space. The purpose of directing student attention could take three forms: communicating what the current task is, providing an aid to understanding, or for students working in groups, maintaining a focal point for collaboration. Both teachers and students would direct the attention of other classroom actors to specific pages, problems, or directions in the student workbook to communicate what the current classroom task was. Teachers and students would also reference specific features or representations in the student workbook or MathWorlds software in an effort to further explain a concept or provide an aid to understanding. When students were engaged in group-work they would also reference specific aspects or features of physical resources to help maintain a focal point for collaboration. By directing student and teacher attention to resources both teachers and students communicated and facilitated classroom goals.

Arguably one of the most important tasks for teachers as they conduct their classrooms is to assess and address student understandings. One of the most common strategies teachers used was to call on individual students to interpret a particular learning resource and perform instructional tasks. This could take the form of asking a student to share an observation, answer a workbook question aloud, or even lead the class through an activity. Teachers in our study also sought to capitalize on some students’ abilities to communicate their understandings to others by either directly asking students to help one another or by arranging the students into small groups. Again, when we focus on student behavior we see that students also assessed and addressed either their own understandings or the understandings of other students in the class. Frequently students would request attention from their teachers when they had a misunderstanding, but they would also turn to their peers. When students were working through the misunderstandings of a peer they would frequently share and direct attention to other resources available to them (such as their own workbooks). In all of the classrooms, students would interpret learning resources, and teachers and students would utilize specific resources for the purposes of advancing student understanding.

Throughout the course of our observations, we see that the teachers conceptualized and framed the use of certain resources through the course of their instruction in a number of different ways. Teacher G expressed in her post-unit interviews that it was hard for her to share her students’ attention with the technological resource. In her instruction, Teacher G framed the use of the software as something only to be used when directed or when given permission. This framing of resource use was echoed in the student behaviors. Students in Teacher G’s class saw the use of the software as “cheating” in some cases, and at other times simply as something you needed to ask permission to use first. Similarly, Teacher M framed her use of the laptop and projector as
something the students were “in control” of and yet something that kept the students “together”. Students in her class were observed to direct use of the SimCalc resources (such as requesting that they run the simulation again or change the lines on the simulation graph), yet only one student was given direct access to the technology. Teacher B and Teacher C shared their perceptions on student sharing of laptops in their interviews as either a benefit to students (Teacher B) or something of possible concern (Teacher C). Teacher B and Teacher C both acted on their perceptions. Teacher B always arranged her students into pairs (which Teacher C did not). Teacher C would ask her students to “switch drivers” in an effort to mitigate any issues of inequitable student work. These teacher actions again were shadowed in student actions, though perhaps in unexpected ways. Students filmed in Teacher B’s classroom did not demonstrate equitable resource sharing practices, while students in Teacher C’s classroom would “switch drivers” or make resources available to other students even when Teacher C did not direct them to.

The case study teachers and students established practices that shaped the nature of how resources were enacted as learning resources. The secondary coding and analysis allowed us to identify five themes that represent constellations of behavior surrounding the enactment of learning resources: student roles and responsibilities, students’ physical proximity and orientation towards resources, how student attention was managed by teachers and students, how student misunderstandings were addressed by teachers and students, and the social framing of student resource use. While all of the classrooms engaged in the construction of social norms surrounding the access and use of learning resources, the particulars of these behaviors and enactments differed. The five themes capture the “hows, whens, and whys” particular students in particular classrooms accessed resources at particular moments.
7 Theoretical Constructs For Understanding Classroom Resources

From a first round coding and analysis of the case study data we see that the observed classrooms varied not only in their classroom set-ups but also in a number of different ways. Teachers and students interacted with the SimCalc MathWorlds software, the SimCalc student workbooks, and with one another to varying degrees under a variety of different circumstances. From the second round coding and analysis we are able to identify and focus on the moments in which learning resources were enacted, that is, when they were arranged, allocated, modified, moved, attended to, interpreted, and given value to in terms of the social or moral order of the classroom. By focusing on the enactments of learning resources and the social norms surrounding student access to resources we begin to see the “hows, whens, and whys” particular students in particular classrooms used particular resources at particular moments.

Literature on classroom resource arrangements and teacher instructional strategies offer two theoretical constructs for describing the socio-physical classroom spaces and the nature of how resources are made available to students: “resource richness” and “teacher withitness”. However, when we compare the descriptions of resource richness and teacher withitness to the five themes presented in the previous chapter we see that these constructs need elaboration or possibly redefinition. In the following sections I review literature on resource richness and teacher withitness and discuss these constructs with respect to the ways learning resources were enacted in the case study classrooms. This discussion results in two new proposed theoretical constructs for describing socio-physical classroom setting and teacher and student strategies for managing resource use: socio-physical resource richness and resource use withitness.

7.1 Physical and Social Resource Arrangements

As discussed in the related work section of this document, the physical characteristics of classrooms have been shown to impact, or at least correlate with, some student engagement and student learning measures (Becker et al., 1973; Marx et al. 1999; Montello, 1988; Rivlin & Weinstein, 1984; Totusek & Staton-Spicer, 1982; Weinstein, 1985). For instance, students who are seated closer to significant targets of perception or interaction (such as the front of the classroom) perform better and engage more than other students who are seated farther away (Becker et al., 1973; Marx et al., 1999). Also, when students are allowed to choose their own seats, the students who chose to sit in the frontal and central seats have been found to be more creative, aggressive, and competitive than their peers seated elsewhere (Totusek & Staton-Spicer, 1982).

When we focus on the literature of computing technology placement in classroom spaces, researchers often contend that positive effects can only arise when classrooms have a “richness” of technology presence (Caporeal & Thorngate, 1984; Coley, 1997; McInerney, 1989; Shaw, 1996). The availability or richness of computing presence in classroom spaces has been measured by the ratio of students to computers in some cases (Coley, 1997; Shaw, 1996), and as the number and type of use instances in others (Caporeal & Thorngate, 1984; McInerney, 1989). Some of the contended positive effects of technology “rich” classrooms are positive changes in
teacher practices, such as teachers using more of a constructivist student-centered teaching style (Gearhart et al., 1990), increases in student collaboration (Becker, 1991), and increases in a variety of student engagement, collaboration, and performance measures (Means & Olson, 1995; Inkpen et al., 1995). However, there is a growing body of research that suggests the presence and even “richness” of technology in classrooms does not necessitate teacher practice and student learning improvements (Cohen, Raudenbush, & Ball, 2002; Grubb, 2008; Zhao & Frank, 2003). In fact, some research has demonstrated that the introduction of technology in classroom spaces can have negative effects, such as teachers using a more teacher-centered, didactic teaching style (McCreary, 2001).

Furthermore, some of the physical requirements to store and use technology may have other second-order negative effects. Computer stations may take-up a significant amount of desk real estate, and therefore make it difficult if not impossible for students to use a variety of resources at once. Mobile laptop storage carts can also take up a significant amount of classroom floor space and the laptops themselves require regularly charged batteries. When the classroom has many computer stations then they will require either a significant amount of power cords and power strips (which may cause hazards of their own), or to be positioned along the perimeters of the rooms where electrical outlets are located. Even when a teacher simply uses a single computer projected onto a wall there are accommodations that must be made due to physical limitations of the technology, such as having to turn off overhead lights to make the projection visible.

When we examine the micro-ergonomics surrounding classroom technologies we see a seemingly limitless number of factors that can impact how and when teachers and students use technology. For instance, the ergonomics of individual teacher and student workstations, the arrangement of student desks, and the location of resources can deeply influence student and teacher actions. Furthermore, there are an equally large number of school macro-ergonomic factors, such as the teacher’s agency or control over technology use and principal support, that can effect student and teacher access to resources, success with resources, and contentedness with their classroom and resource set-ups (McCreary, 2001).

The purpose of the current study was not to enumerate all of the micro- and macro- ergonomic attributes of each case-study classroom, but rather to attend to and describe the socio-technical settings as that influenced student, teacher, and resource interactions. In the following sections I’ll review the physical arrangements of resources in each of the case-study classrooms and describe socio-physical factors that influenced student and teacher behavior and their interaction with resources. Specifically, I’ll describe the arrangements of students in relation to key focal points of interaction and then how these arrangements relate to behavior patterns or themes noted in the previous chapter. This discussion leads to the introduction of a new theoretical construct, called socio-physical resource richness, that can be used to describe the degree of physical and social access students have to resources.
Teacher G’s students engaged with SimCalc resources in two different classroom settings: the school computer lab and Teacher G’s typical classroom. Figure 22 depicts the physical arrangement of both settings, where white squares represent student desks, black rectangles represent laptops, and the gray rectangles represent where the teachers generally stood when they engaged in whole-class discussion. The figure also demonstrates the direction students were facing when they were looking at the closest technological resource (with black arrows) and when they were looking at their teacher (with gray arrows).

In the computer lab, each student had access to his or her own computer. Also, when Teacher G engaged in whole-class discussion, she would continuously walk around the center of the computer lab behind the student workstations. When we consider that some student learning and engagement measures have been shown to correlate with student proximity to key focal points of interaction, the computer lab setting has a desirable trait: the students had equal access/proximity to SimCalc MathWorlds and their teacher when she engaged in whole class discussion.

However, as illustrated in Figure 22, the students were unable to keep both SimCalc MathWorlds and their teacher within their field of vision in the computer lab. If they needed to or desired to interact with a SimCalc MathWorlds simulation, it was necessary to have their back to their teacher. If they needed to or desired to see and interact with their teacher, then they had to turn away from their computers. This division of student attention was apparent to Teacher G, as she described in her post-unit interviews (reported in Sections 5.1.1.1, 5.1.1.2, and 6.5.1).

Furthermore, the division of student attention between the technology resource and their teacher affected Teacher G’s interactions with her students. As captured by the theme “Values assigned to resources and framing of resource use” (Section 6.5), when Teacher G wanted her student’s
attention she would ask them to take their hands off the computers and/or turn around in their seats. This led to the technology resource being socially “off-limits” to students at certain points of time in a given class session.

In Teacher G’s usual classroom, students did not directly interact with SimCalc MathWorlds but rather observed the software being used by their teacher. SimCalc MathWorlds was projected onto a TV screen mounted from the ceiling in a corner of the classroom space. In this setting, there was no apparent division of attention between the technology resource and the teacher. Indeed, the teacher ran the SimCalc simulations as part of a whole-class discussion. This obviated the need for Teacher G to re-direct student attention away from the technology resource, but at the expense of relative student proximity and access to resources and key focal points of interaction. Students who sat at the front of the classroom were physically closer to both their teacher and the technology resource, while students towards the back were farther away. Furthermore, the students did not have individual control of the technology resource, and could only observe a simulation for the number of times Teacher G chose to run it.

The physical arrangement of the computer lab and classroom spaces also presented different possibilities and limitations in the ways students had access to and could interact with their peers. In the classroom setting, Teacher G was observed to ask her students to move their seats so they could form small student groups and engage in small-group work (described in Section 6.2). It was not possible for Teacher G or her students to move the student workstations in the computer lab setting. However, students still engaged in small group work with modified patterns of interaction. In the computer lab setting, students seated in the middle of a small group were observed to relay information back and forth across the different group members, and make heavy use of the physical resources available to direct their peers attention to focal points for collaboration (described in Section 6.3.2).

### 7.1.2 Socio-physical setting Teacher C and Teacher B’s classrooms

![Diagram of Teacher C and Teacher B's classrooms](image)

**Figure 23.** Teacher C's classroom (left) and Teacher B's classroom (right) with arrows demonstrating the direction students faced when looking at the closest technological resource (in black) or their teacher (in gray).
Teacher C and Teacher B had very similar classroom set-ups and arrangements of resources. In both classrooms students were arranged into pairs and they would balance a shared laptop between their two desks. Figure 23 depicts the physical arrangement of both classrooms, where white squares represent student desks, black rectangles represent laptops, and the gray rectangles represent where the teachers generally stood when they engaged in whole-class discussion. The image also demonstrates the direction students faced when looking at the closest technological resource (with black arrows) and when they faced their teacher/front of the classroom (with gray arrows).

In terms of proximity to key focal points of interaction, students in Teacher C and Teacher B’s classroom were equally close to technological resources, but they were not equally close to their teacher or the front of the classroom. Students at the front of the classroom were close to their own, shared laptops, the projection of SimCalc MathWorlds, the projection of transparencies, and their teacher when she engaged in whole-class discussion. On the other hand, students towards the back of the classroom were equally close to their shared laptops as their peers in the front of the classroom, but they were farther away from the other focal points of interaction such as the overhead projections and their teacher. If we defined “resource richness” to be the degree of student proximity and access to resources, then we can see that the front rows of Teacher C and Teacher B’s classrooms were more “resource rich” for their students than the rows of desks in the back of the classroom.

The students in Teacher C and Teacher B’s classroom were arranged into groups of two for the purpose of sharing the limited laptop resources. A consequence of this arrangement was that students were better able to engage in student-student collaboration with their neighbor. This was considered to be a desirable and intended consequence in Teacher B’s opinion, and a potentially problematic consequence in Teacher C’s opinion (described in Section 6.5.3). Furthermore, the increase in student-student collaboration may have also altered what could be considered one of the micro-ergonomic factors of the classroom space: overall noise level. An increase in student discussion would increase the generally volume and noise level of the classroom. There is evidence to suggest that this was something that Teacher B reacted to, since she was observed to repeatedly “shush” her students during every observed class session (reported on in Section 5.1.2.4).

In contrast to the computer stations in Teacher G’s computer lab, the laptops in Teacher C and Teacher B’s classrooms could be and were moved and rearranged by both the teachers and the students (described in Section 6.2). In some instances, the teachers requested the laptops to be moved as part of classroom management tasks. Teacher B was observed to ask her students to close their laptops when she felt she did not have their attention. Teacher C also asked her students to close their laptops when she felt she needed their attention, and she reported that the laptops were a classroom management concern in her post-unit phone interviews (reported in Section 5.1.2.2). Furthermore, students were observed to move the laptop resource to both (1) gain more individual access to the resource and (2) facilitate sharing and collaboration with their partner. The social processes for student movement of resources were negotiated between the student pair. This negotiation manifested as a conflict between the students in some cases, or appeared as seamless interchanges in others (described in Section 6.2.2).
7.1.3 Socio-physical setting Teacher M’s classroom

Teacher M’s students were arranged into student quads, or groups of four, where the desks were arranged such that the students faced the center of the room. Figure 24 depicts the physical arrangement of Teacher M’s classroom, where white squares represent student desks and the technological resources (laptop, projector, and overhead transparency projector) and the gray rectangle represent where the teacher generally stood when she engaged in whole-class discussion. The figure also demonstrates the direction student desks were orientated (with white arrows) and the direction they faced when they were looking at their teacher/front of the classroom. As noted in Section 5.1.3, a couple students routinely moved their desks at the beginning of class periods. When they moved their desks, they moved them closer to the center of the room with their desks orientated towards the front of the classroom.

In Teacher M’s classroom, all of the technological resources were located at the front of the classroom, with the exception of a few calculators, which were distributed to a small number of students each class period. Also, when Teacher M engaged in whole-class discussion, which she did for the majority of most class sessions, she was located at the front of the class. If we again conceptualize “resource richness” as the degree of student proximity and access to resources, then the front and central areas of the classroom were the “richest” areas for students to be seated in. Out of all the students in Teacher M’s classroom, we could argue that “Travis”, the boy in charge of running the laptop resource, had a seat with the most resource richness. He had a direct line of sight to the teacher and the overhead projections, as well as access to the single laptop computer in the classroom.

Unlike Teacher G’s computer lab and Teacher C and B’s classrooms, none of the students had individual or even shared control of the technological resource. (That is, with the exception of
Travis.) Despite this lack of physical proximity and control of SimCalc MathWorlds, Teacher M’s self-report and observed teaching practices suggest that she endeavored to give her students social control of the technology (described in Section 6.5). Throughout the course of a SimCalc lesson, Teacher M would ask her students to verbalize what actions she, Travis, and “the calculators” (students allocated a calculator that class period) should take with regards to completing a given problem.

### 7.1.4 Socio-physical resource richness

Past research on socio-physical classroom settings suggest that student proximity to key focal points of interaction can influence or affect student outcome measures (Becker et al., 1973; Marx et al. 1999; Montello, 1988; Rivlin & Weinstein, 1984; Totusek & Staton-Spicer, 1982; Weinstein, 1985). Researchers interested in embedding technological resources into classroom socio-physical settings have argued that the “richness” of technology presence is a crucial element, where richness can be defined as the ratio of students to technological resources or the number of student-use instances (Caporeal & Thorngate, 1984; Coley, 1997; McInerney, 1989; Shaw, 1996). However, other literature in the Learning Sciences that examines the success of interventions more broadly suggest that the success of the intervention hinges on the way the new resources are used (Cohen, Raudenbush, & Ball, 2002; Grubb, 2008). When this research is considered collectively, we see that the physical nature and set-up of classroom spaces, including the arrangement and availability of resources, influences the manner in which resources are interacted with by teachers and students. Furthermore, the nature and quality of classroom resource interactions ultimately affects the nature of what students engage with and learn.

To trace the influence of the different classroom arrangements on student behaviors, I described the socio-physical settings and resource arrangements of each of the case-study classrooms in relation to the socio-resource use norms captured by the five emergent themes (Sections 7.1.1, 7.1.2, and 7.1.3). In describing the relationship between socio-resource use norms and the classroom space, I borrowed and expanded the term “richness” to include not only technological resources but also any other classroom resources, including the teacher and student peers.

*socio-physical resource richness* – the degree of student physical and social access to resources.

The resulting socio-physical resource richness in the case-study classrooms was driven by physical and social properties of the space and resources. The different physical classroom arrangements yielded different student proximities to key focal points of interaction. For example, in Teacher G’s computer lab, each student was equidistant to the technological resource, their peers, and their teacher. Whereas in the other observed classroom settings, there were varying degrees of proximity and access to resources for each of the student seats. Also, in each of the case-study classrooms, we observed the establishment of social norms surrounding the use and access of resources. The arrangement of Teacher G’s computer lab made it impossible for the students to keep both the technological resource and their teacher in their line of sight. This division or tension between student attention on the technological resource versus student attention on their teacher led to the establishment of social norms that regulated when students should attend to either resource.
It is important to note that the establishment of classroom social norms is always a “joint accomplishment”. Even in the cases where the social construction of when and how resources should be used seem to stem directly from teacher action alone (ie. Teacher G saying, “where should your hands be right now”), it is important to remember that students play their part by coming to act in accord with the teacher’s expectations. Therefore this framing of how resources are used is not just an overlap in the teacher and students’ individual understandings, but rather, the joint construction of social understandings and norms (Yackel & Cobb, 1996). In the words of diSessa and Cobb (2004), “the teacher and students together constitute a community of validators” (p. 94), where judgments on the appropriateness and inappropriateness of behaviors are negotiated. In this respect, the socio-physical resource richness of a classroom is defined by physical properties of the classroom space and the negotiated social-norms presented within the established classroom culture.

If it is truly the nature and quality of classroom resource interactions that ultimately affect what students engage with and learn, then the current term, “resource richness”, is insufficient for describing critical classroom factors. We need to describe the degree of student physical and social access to resources. This is similar other arguments made in the CSCW field that the critical properties of appropriate behavior framing and collaborative interactions are not inherently rooted in properties of physical spaces, but rather in places (Harrison & Dourish, 1996). “Place” is a term used in architecture and urban design to describe the deeply rooted sets of mutually held cultural understandings of behavior appropriateness. Classrooms are not simply spaces, but rather places that inherently evoke shared cultural understandings of behavior appropriateness. Furthermore, classroom places are shared by teachers and students who co-develop shared understandings and social behavior norms surrounding the use of resources. Therefore, by defining the socio-physical resource richness to incorporate both physical and social aspects of resource use, we can begin to look at how different classroom place set-ups affect the quality and nature of student resource interactions.

### 7.2 Resource Use “Withitness”

Past research has shown that factors such as teachers’ degrees and certifications do not necessarily correlate with the quality of teacher instruction (Pianta, 2007), but rather that excellent teachers have “bundles of techniques” they employ. Teachers must moderate their classrooms and endeavor to send signals that help guide student behavior as well as further student learning. This means that teachers should act with an intuitive awareness of what their students are doing and should do next (Kounin & Sherman, 1979). The “bundles of techniques” and “intuitive awareness” teachers must possess to effectively manage their classroom has been described as teacher “withitness”, and it is a topic of rising concern to researchers in the Learning Sciences (Gladwell, 2008; Kounin & Sherman, 1979).

While the term “withitness” has been used to describe effective teaching strategy over the past decade by Jacob Kounin as well as other Learning Sciences researchers, it was most recently popularized by Malcolm Gladwell in an article he wrote for the New Yorker titled “Most Likely To Succeed: Why do we hire when we can't tell who's right for the job?” (2008). In the article he describes what “withitness” means and how hard it is to measure and assess:
“Another educational researcher, Jacob Kounin, once did an analysis of “desist” events, in which a teacher has to stop some kind of misbehavior. In one instance, “Mary leans toward the table to her right and whispers to Jane. Both she and Jane giggle. The teacher says, ‘Mary and Jane, stop that!’” That’s a desist event. But how a teacher desists—her tone of voice, her attitudes, her choice of words—appears to make no difference at all in maintaining an orderly classroom. How can that be? Kounin went back over the videotape and noticed that forty-five seconds before Mary whispered to Jane, Lucy and John had started whispering. Then Robert had noticed and joined in, making Jane giggle, whereupon Jane said something to John. Then Mary whispered to Jane. It was a contagious chain of misbehavior, and what really was significant was not how a teacher stopped the deviancy at the end of the chain but whether she was able to stop the chain before it started. Kounin called that ability “withitness,” which he defined as “a teacher’s communicating to the children by her actual behavior (rather than by verbally announcing: ‘I know what’s going on’) that she knows what the children are doing, or has the proverbial ‘eyes in the back of her head.’” It stands to reason that to be a great teacher you have to have withitness. But how do you know whether someone has withitness until she stands up in front of a classroom of twenty-five wiggly Janes, Lucys, Johns, and Roberts and tries to impose order?” (Gladwell, 2008)

Gladwell’s article asserts that great teachers undoubtedly have “withitness”, but that “withitness” itself is a difficult trait to identify and measure. When we turn to the literature on teacher “withitness”, we see that a number of definitions have been put forward for the term. The following is a list of definitions and descriptions of “withitness” gathered from a variety of publications geared for researchers and teachers/practitioners:

- “‘Withitness’ involves a keen awareness of disruptive behavior or potentially disruptive behavior and immediate attention to that behavior; of [all] the dimensions [of effective classroom management], it is the one that most consistently separates the excellent classroom managers from the average or below-average managers” (Marzano, 2003, p.5).
- “[D]ifferences between effective and ineffective classroom managers was not in how they handled the disruptive behavior of students, but in the disposition of the teacher to quickly and accurately identify problem behavior or potential problem behavior and act on it immediately.” (Marzano, 2003, p. 66-67)
- “Remaining ‘with it’ (aware of what is happening in all parts of the classroom at all times) by continuously scanning the classroom, even when working with small groups or individuals. Also demonstrating this withitness to students by intervening promptly and accurately when inappropriate behavior threatens to become disruptive.” (Brophy, 1996, p. 11)
- “Teachers who exhibit withitness share the following traits: address misbehavior issues immediately, direct discipline at the offender rather than the entire class, clearly state to the offender the rule that was broken, [and] prioritize discipline issues that must be handled first.” (Kovarik, 2008, p. 10)

These definitions of withitness, as well as the description by Malcolm Gladwell, largely focus on what it takes to be an effective “classroom manager”. That is, what techniques and strategies teachers must have and use to effectively mitigate and stop disruptive behavior while simultaneously promoting appropriate behavior.
If we turn to the data and analysis presented in this report, we see that teachers and students were actively engaged in creating social norms surrounding the use of resources. In particular, we observe that teachers would direct and redirect student attention to resources as part of their classroom management task. For example, all of the case-study teachers were observed to redirect student attention to specific resources, such as specific pages in the student workbook, to help communicate to students what the current classroom task was. It was not uncommon for a teacher to look over a student’s shoulder and then redirect that student to a specific page or problem in the workbook if the teacher felt the student was off-task. When we consider that one trait of teachers with “withitness” is knowing what students are doing and should do next, we can identify teacher direction of student attention to resources as one possible demonstration of “withitness”. Teachers were directing student attention to resources as part of ongoing effort to be effective classroom managers.

However, for the most part, teachers endeavor to be, and in fact are required to be, more than good “classroom managers”. The case-study teachers reported on in this document, in particular, are mathematics teachers. That’s is, their job is to teach their students mathematics while simultaneously creating a classroom that "works" in terms of classroom management concerns, student abilities, time management, principal and community expectations, and state and school standards assessment goals. In short, they must try to be “with it”, where the “it” is a host of different goals and concerns.

One of the primary “its” or goals that a teacher is concerned with, student learning, is one of the most difficult to assess in the moment while class is ongoing. Student learning is not easily witnessed (unfortunately, light bulbs do not appear over student heads). Yet teachers are expected to and endeavor to provide the signals to keep students on the right track. Similar to the examples provided of teachers directing student attention to specific resources as a strategy for keeping “withit” in terms of classroom management, we see examples of teachers directing students to specific resources as a strategy to assess and moderate student learning. Take for example, the following transcript from one of Teacher C’s class sessions, already reported on in Section 6.3:

[00:36:45.21] Teacher: “What else did you see on this one?”
[00:36:47.21] Teacher: “Because lots of you were using the step button.”
[00:36:52.04] Male Student: “Oh”
[00:36:53.27] Teacher: “What do you think? What are some things that we could add?”
[00:36:57.22] Male Student: “Oh um Kim, he went 5 meters per second. Like at meter 5 it would be 1 second.”
[00:37:09.20] Teacher: “Okay, wait, say that again.”
[00:37:12.16] Male Student: “When you hit the step button, he goes 5 every....like he's on the line by fives every time.”

--Transcript from video 27912_112706_Cam2

In this example, Teacher C directs her students to one particular resource: the step-button functionality in SimCalc MathWorlds. Her direction to that particular resource provides scaffolding for her students to remember and describe a phenomenon important to understanding
what the simulation depicts. Teacher C’s direction of student attention to a resource, in this instance, is a means for her to facilitate student learning.

In the classrooms described in this report we see that teachers used and referenced learning resources at times to (1) manage student behavior and (2) assess and address student learning. Teachers would direct student attention and moderate student access to resources in response to both apparent classroom management issues as well as to facilitate student learning. We could describe this active management of student attention to resources as resource use withitness. Similar to how previous researchers have described withitness as “intuitive awareness” and “bundles of strategies”, resource use withitness specifies the awareness and strategies required to effectively manage student use of resources. Therefore, teachers with a high-degree of resource use withitness are able to manage student attention to resources in service to many concurrent classroom goals, such as classroom management concerns and student learning.

resource use withitness – effective strategies for managing student access to, attention to, and use of resources.

Furthermore, the act of assessing and moderating student behavior and learning was reflected in the observed student behavior. Students engaged in a number of different behavior patterns that indicated that they were actively involved in the process of moderating their behavior and their peer’s behavior as well as assessing and addressing the misunderstandings of themselves and their peers. Students did this by arranging, rearranging, and directing attention to resources in the classroom space. For example, students in all of the case-study classrooms were observed to communicate with one another, and in the classrooms where students had direct access or shared access to computers (in Teacher G, Teacher C, and Teacher B’s classrooms) students would frequently collaborate with one another while they completed workbook activities. During these student collaborations students would direct their peers’ attention to resources, such as the workbooks and SimCalc MathWorlds simulations, to help communicate what the classroom task is, to provide aids for student understanding, or to provide focal points for their continued collaboration.

When students use resources to communicate what the classroom task is, they are demonstrating one of the espoused hallmarks of teacher “withitness” – good classroom management. Furthermore, when students use resources to help provide an aid to understanding for their peers and to provide focal points for student collaboration they are furthering another important classroom goal: increased student learning. There is some indication that these behavior patterns could be used to describe how the students were epistemologically framing the task at hand (Scherr & Hammer, 2008), but we should also consider that students who excel in these classrooms might also possess bundles of strategies they use with intuition or “withitness”.

In this section I have put forward a definition of resource use withitness. Resource use withitness is the collection of strategies for managing student access to, attention to, and use of resources. This definition of resource use withitness borrows and extends the general term “withitness” that has been used to describe strategies for effective classroom management. However, the definition of resource use withitness I presented here can be used to characterize strategies for promoting a multitude of classroom goals through the use of resources. These classroom goals
include student learning and student collaboration as well as appropriate student behavior. This conceptualization of resource use withitness stems from the case-study observations, in that all of the case-study teachers were observed to direct and redirect their student attention to resources as a means to manage classroom behavior and to promote student learning. Furthermore, I have deliberately defined resource use withitness such that it could be applied to teacher and student management of attention to resources. Students in the case-study classrooms actively managed their attention as well as the attention of their peers to resources to further goals such as student learning and student collaboration. When we consider that the classroom is an ecosystem containing a number of actors and artifacts that interact with one another, the resource use withitness of the teachers and students may go far in determining the “survival” and success of any one “species”. Future work that investigates student and teacher use of resources should further explicate teacher and student resource use withitness and examine which strategies meet with the most success.
8 Discussion: The educational resource design problem

In recent years, researchers in the fields of HCI and CSCW have become more concerned with technology design and use in the context of education. The first International Conference on Computer-Supported Cooperative Learning (CSCL) was held in 1995, and has been held bi-annually ever since. Also, more reports on educational resource design and evaluation have been presented at conferences like the International Conference on Computer-Human Interaction (CHI).

Table 26. Titles of CHI conference sessions dedicated to discussion of educational technologies

<table>
<thead>
<tr>
<th>Session Name</th>
<th>CHI Conference Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>“Learning”</td>
<td>2011</td>
</tr>
<tr>
<td>“Classroom Technologies”</td>
<td>2010</td>
</tr>
<tr>
<td>“Education and Science”</td>
<td>2009</td>
</tr>
<tr>
<td>“Learning Challenges”</td>
<td>2009</td>
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<tr>
<td>“Using tabletops for education, science, and media”</td>
<td>2009</td>
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<tr>
<td>“Learning Support”</td>
<td>2008</td>
</tr>
<tr>
<td>“Learning and Education”</td>
<td>2007</td>
</tr>
<tr>
<td>“Educational &amp; help systems”</td>
<td>2005</td>
</tr>
</tbody>
</table>

At the CHI 2000 conference, only one accepted paper reported on the design and use of an educational technological tool (Frei et al., 2000). Since that time, the number of papers reporting on the design and use of educational technologies has increased. In 2005 there were two conference sessions dedicated to the design of technology for education and learning, and since 2007 there has been at least one session dedicated to educational technologies at every CHI conference (Table 26). This indicates there are more researchers and designers interested in developing technology for educational settings, including classrooms, museums, and the home. These designers and researchers largely believe that technology has the power to enhance student-learning experiences. Indeed, the SimCalc MathWorlds research trajectory provides a compelling example of such a project.

Arguably, in educational technology design and evaluation projects, “teacher technology adoption” issues are often considered separate and secondary to issues of “student technology use”. When “increase student learning” is the central goal of a technology design project, data on student experience naturally becomes a central component of the evaluation. In some projects, data on teacher use and opinion are only gathered “post-hoc”. That is, teacher level data are collected only after a design idea has already crystallized. One notable exception would be projects where a participatory-design methodology is used and teachers are invited to be members of the design team. However, even participatory design projects can fail to gather any “wide-scale” data on teacher use and opinion until after the design has gone through several iterations.
A consequence of not incorporating teacher experience early into the design program is that the resulting technology could not be “compatible” or “adoptable” for real-world teaching and learning contexts (Rogers, 2003). Indeed, there have been a number of educational technologies that have been designed to increase student learning and yet have not been adopted by teachers and schools necessary for the technology to have real impact (Convery, 2009). Failing to recognize teachers as the classroom ecosystem “keystone species”, or as gatekeepers to resources, results in the development of technologies that may have potential to increase student learning but are largely unusable to teachers in the classroom context (Zhao & Frank, 2003).

Simultaneously, there are an increasing number of technologies used broadly by teachers and schools, which have no observed impact on student learning (Grubb, 2008; Zhao & Frank, 2003). These technologies include email, calendaring systems, web-page development tools, and presentation software (such as power-point). These technologies may make it easier for teachers to accomplish some tasks, but they do not provide any noticeable benefit to students (Grubb, 2008). There is an apparent paradox or conflict when designing technology for classroom settings: designing for the student experience, to facilitate student learning, versus designing for the teacher experience, to facilitate teacher adoption.

However, when we examine case studies of student-teacher-resource interactions we see that issues of student experience do not exist in isolation from teacher experience. In the classroom ecosystem, teacher-resource interaction experiences ultimately influence student-resource interaction experiences. For example, after Teacher M experienced what was an unsuccessful installation of SimCalc MathWorlds on the school computer lab machines, she decided to only use SimCalc MathWorlds on a single projector displayed at the front of her classroom. To Teacher M, this was a decision that improved her experience, yet it had deep impacts on the way her students interacted with the software. Furthermore, what teachers perceive to be the value of student-resource interactions shapes their day-to-day pedagogical decisions regarding resources. When Teacher B or Teacher C felt that their students were being distracted by the technology, they would reconfigure their classroom set-ups. This usually entailed asking students to close their laptops temporarily or put them away for the rest of the class period. In these instances, Teacher B and Teacher C felt the technology was more distracting for their students than beneficial. Also, teachers in all of the case study classrooms would redirect student attention from one resource to another to facilitate student learning or to address classroom management concerns (described in Section 6.3). All of these teacher decisions on resource configuration and access were based on the teachers’ pedagogical and management concerns, yet they had deep impacts on how the students ultimately experienced the technological resource.

The history of educational technology development and evaluation suggests that the design approach should not and cannot be “design for student learning, and then find ways to increase teacher adoption later”. Educational technology developers need to account for the many social and physical mechanisms present in classroom ecosystems in their designs. However, this is a difficult task. The complexities of the classroom socio-physical setting makes it difficult to assess what values and established social-norms lay on the critical path to successful classroom change (for the purposes of increasing student learning) and successful classroom use (for the purposes of promoting teacher adoption).
In the following sections I first describe how evaluations conducted in complex classroom social settings requires an analytical approach that both presents holistic explanations of classroom socio-physical phenomenon and uncovers the interacting motivations of classroom actors. This is accompanied by an example of a common “pitfall” in incorporating teacher level data into the assessment of a technological tool designed to increase student learning. Then, I present two conceptual/analytical approaches for moving forward: the population of case-study exemplars and the development of ontological categories. These analytical approaches have the potential to both increase understanding of complex classroom social phenomenon and provide a deeper understanding of what any educational technology design program should account for.

### 8.1.1 Evaluation in Complex Classroom Systems and a Possible Pitfall

It seems that when we consider the problem of designing educational resources for classrooms we must consider both: (1) designing for the student-experience, such that student learning is enhanced or furthered by resource use, and (2) designing for the teacher-experience, such that teachers can incorporate the resource into their existing classroom practices and make successful use of it. However, in context, the factors that influence student-experience cannot be teased apart or separated from the factors that influence teacher-experience. The classroom is a complex socio-physical system in which the relationships between actors and resources are entwined and communally constituted.

Designing resources for a complex socio-physical system such as classrooms is difficult work. Indeed, the current history of educational technology development suggests that the classroom ecosystem is one that still holds mysteries for designers and researchers. In the process of developing and evaluating an educational technology, it is not uncommon for researchers to encounter new or even surprising phenomenon that requires a reassessment and reconstitution of working models and theories. In the words of diSessa & Cobb (2004), “discovery of new foci of attention is actually quite common in [educational] design experiments, if not absolutely necessary.” (p. 86)

One surprising phenomenon that may occur through the course of an educational technology evaluation is that even though the technology has been designed with student learning in mind, the teachers say or insinuate that they are not comfortable using the new innovation. For example, in Teacher G’s year-two interview, she described sharing her students’ attention with the computers as something that she had to “adjust” to.

> “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. So sharing that attention with the computer was I guess an adjustment for me.” – Teacher G post-unit interview, Year Two

Or similarly, teachers may alter their use of the innovation in such a way that it deviates from the designers’ vision of use. In some cases, teachers can alter their use of the innovation in such a way that the central catalysts for increased student learning are reduced in impact. These alterations are sometimes referred to as “lethal mutations” (Lamon et al., 1996; Wollman-Banilla, 2002). By way of example, we can discuss Teacher C and Teacher B’s adjustments to the SimCalc unit from year-one to year-two of the study. Specifically, they significantly reduced
the amount of the SimCalc unit they covered. In year one Teacher C and Teacher B taught nearly the entire SimCalc unit. In year two they both taught roughly half of the SimCalc unit and substituted some workbook activities with ones they created themselves. While both Teacher C and Teacher B’s year-two students demonstrated positive learning gains, their reduction of the SimCalc unit is an example of teacher alteration of a resource. It is unclear what affects Teacher C and Teacher B’s alterations ultimately had on their students in terms of deep understanding of mathematics and potential to learn conceptually difficult mathematics in the future.

As researchers, we have a duty to report these surprising phenomena, and discuss their relation or fit within the existing theory of change we are working with. Furthermore, these surprising phenomena may represent an opportunity. New and previously unpredicted phenomenon can help us reject failed theories and establish more accurate and encompassing theories on classroom systems. In the words of diSessa & Cobb (2004), “[f]ailures or surprising successes not infrequently push toward, and sometimes enable, new lines of inquiry, possibly involving new ontologies.” (p.86)

However, while in the process of rebutting surprising or unwelcome research findings, researchers can simply “manage the gap by patching enough to get by, without pulling the surprising occurrence into the core, scientific program.” (diSessa & Cobb, 2004, p.86) This “management of the gap” between an existing theory and phenomenon that runs counter to it is a task that must be carefully done. Specifically, there is a risk of researchers and designers presenting biased interpretations of surprising phenomenon, where biased and incorrect interpretations continue to support a flawed theory and innovation.

It has been argued by Andrew Convery (2009) that biased educational technology designers often operate with a “fundamental conviction that the value of the technology will eventually be vindicated.” (p.29) Furthermore, in the event that unwelcome research findings are presented, biased technology developers “enjoy such a secure belief in the value of the technology that any unwelcome research findings merely illustrate the shortcomings of the researchers” who were charged with the task of evaluating the technology’s design (Convery, 2009, p. 29-30). If educational technology designers and researchers do not take appropriate measures to recognize and reduce such biases in their studies, then their research can look less like systematic and scientific inquiry and more like faith based exercises where they continually defend their convictions.

For example, SimCalc researchers collected and analyzed teacher interview data after both years of the study. The teachers’ self-report on experiences they had teaching with SimCalc became a source of interesting phenomena that was incorporated into other analysis and used to help develop a working model of what “successful SimCalc instruction can and should look like”. (Indeed, one ongoing topic of conversation and debate at SimCalc researcher meetings is the question “what does a SimCalc teacher/classroom/student look like?”) When we focus on Teacher G’s self report, in which she discussed her discomfort with sharing her students’ attention with the technological resource, we see two possible avenues for “managing the gap” between her experience and our assumptions about SimCalc instruction. On one hand, we could argue that Teacher G is simply uncomfortable with technology, and that she may be made to feel more comfortable once she has more training and experience using technology. This, I believe,
would be a biased interpretation of her self-report, one that is in favor of no change on the part of
the SimCalc resources. Furthermore, this interpretation places the burden of change solely on the
teacher. An alternative explanation would be that Teacher G has a valid and essential reason for
being uncomfortable, and that she, as a teacher, knows when she needs to have her students’
attention. This explanation requires more investigative work, and when we turn to case studies of
Teacher G’s classroom we indeed see an explanation for her discomfort. In the computer lab
setting, her students cannot simultaneously face their computer screens and establish eye
contact with their teacher. Teacher G, as well as other teachers, may need to see their students’ faces and
establish eye contact in order to moderate student behavior and assess student understanding.

Convery (2009) goes on to argue that these biased pursuits of rationale for particular
technologies are not harmless. “The unfortunate casualties of this fanciful theory building are
teachers who then become squeezed by being expected to demonstrate in practice the success of
this untested (but much celebrated) educational technology” (Convery, 2009 p. 33). In some
instances, these technologies are promoted “without waiting to scrutinize whether the technology
can be realistically deployed across a range of teaching contexts.” (p.34)

I would go on to argue, that not only are teachers potential victims of biased educational
technology development and evaluations, but that the field of educational technology
development and research also suffers. When we fail to sufficiently grapple with and account for
surprising phenomenon we miss an opportunity to increase general knowledge about the
classroom ecosystem, and thereby blind ourselves to possible avenues for innovation.

8.1.2 Moving forward

To move the field of educational technology development forward, we must find analytical and
theoretical pathways that help us gain the critical understanding of classroom contexts required
to (1) design for the classroom system and (2) protect ourselves from interpretive bias. Convery
(2009) suggests that to do this, we must move on from asking questions such as “how can we
improve student learning with technology?” to more “radical” questions, such as “why certain
technology doesn’t help certain learners in certain contexts?” (p.39) This alternative mode of
inquiry has the potential to push the field towards more nuanced understandings of educational
technology use and affect. However, questions such as these are difficult to approach. The
alternative research question he poses requires that we first establish and clearly articulate whom
“certain learners” may be and what “certain contexts” may look like. Indeed, at the root of his
argument is the notion that learning is a context dependent activity, and that the collective field
of educational technology development has failed to accurately account for the relationships
between design, student learning, and classroom context.

Kuhn (1987) has argued that a discipline without a large number of thoroughly executed case
studies is a discipline without systematic production of exemplars, and that a discipline without
exemplars is an ineffective one. Indeed, the current state of affairs in educational technology
development suggests that we have not been able to establish the requisite knowledge of context-
dependent classroom phenomenon in order to be widely effective. Case studies, such as the ones
reported in this document, can be used provide a more grounded and practical understanding of
context-dependent classroom phenomenon. Flyvbjerg (2001) argues that case studies “generate
precisely that concrete, practical, context-dependent knowledge that makes it possible to move
from lower to higher levels in the learning process.” (p.71) That is, only through concrete experience and practice can we move from rule-based rationality to more intuitive and holistic understandings. Or as Eliot Eisner has suggested, well-chosen case studies and exemplars can help raise our understanding of classroom phenomenon to the expert or “connoisseur” level (Eisner, 1997).

Furthermore, the rule-based understandings of classroom and school phenomenon afforded by quantitative methods may be insufficient for our field. Flyvbjerg (2001) argues, “in the study of human affairs, there exists only context-dependent knowledge.” (p.71) That is to say, cultural and social phenomena are inherently context-dependent. If our goal is to create positive change in the classroom context, then we need methodologies that help us uncover the context-dependent classroom phenomena.

One often-contested “flaw” with the case-study approach is its lack of “generalizability”. In his article “Five Misunderstandings about Case Study Research”, Flyvbjerg (2006) argues that this is not true, and that the generalizability of case studies depends on the case selections. In his words:

“Galileo’s rejection of Aristotle’s law of gravity was not based on observations ‘across a wide range,’ and the observations were not ‘carried out in some numbers.’ The rejection consisted primarily of a conceptual experiment and later on of a practical one. … Galileo’s experimentalism did not involve a large random sample of trials of objects falling from a wide range of randomly selected heights under varying wind conditions and so on… Rather, it was a matter of a single experiment, that is, a case study, if any experiment was conducted at all.”
- Flyvbjerg, 2006, p.225

He goes on to suggest that the generalizability of case studies can be increased by strategic selection of critical cases. Atypical or extreme cases often reveal more information because they “activate” more actors and more basic mechanisms in the situation studied (Flyvbjerg, 2006).

“[F]rom both an understanding-oriented and an action-oriented perspective, it is often more important to clarify the deeper causes behind a given problem and its consequences than to describe the symptoms of the problem and how frequently they occur.”
- Flyvbjerg, 2001, p.78

Case studies afford opportunities to find the root causes behind some of the surprising or unwelcome findings educational technology designers and researchers may come across.

Again, if we turn to the example of Teacher G expressing her discomfort with sharing her students’ attention with the technological resource, the deeper root cause of her discomfort was only uncovered during the course of analyzing case-study data of her class. Arguably, understanding the root cause of her discomfort is more valuable to us than mere statistics on how often she and other teachers expressed these opinions. Case studies afford an opportunity to explain root causes of classroom phenomena that stand on the pathway to resource effectiveness and adoption.
Beyond the systematic development of exemplars or case studies, which can raise our understanding of classroom phenomena to a higher level, we need to develop lasting theories that designers can use and act upon. Indeed, the field of educational technology development is one that requires both understanding and action.

Design-research is a relatively new and still evolving methodology that shows promise and has gained popularity in the Learning Sciences. Design-research studies, in principal, are iterative, situated, and theory-based attempts simultaneously to understand and improve educational processes (diSessa & Cobb, 2004; Cobb et al., 2003). Thus design-research represents a methodology that pursues both understanding and positive action simultaneously.

Currently, “theory” can mean different things and stand in relation to design-based research in a number of different ways. In practice, design-based researchers tend to “follow their noses” and do the work of science as they understand it. Design-based researchers build and operate on working theories that they iteratively restructure and redefine as the gather and analyze data. Unfortunately, this process of opportunistic data gathering and just-in-time analyses leaves little time for researches to develop and articulate extended theory rationale for public explication (diSessa & Cobb, 2004).

In their paper titled “Ontological Innovation and the Role of Theory in Design Experiments” diSessa and Cobb (2004) argued that theory should take a more prominent role in design-based research, and that theories generated from DBR should “do real design work” in generating, selecting, and validating design alternatives. They go on to argue that one set of theories that design-based researchers are poised to contribute are “ontological innovations” – the invention of new scientific categories, specifically categories that do useful work in generating, selecting among, and assessing design alternatives. The generation of scientific categories can help researchers make distinctions that really make a difference, ignore the ones that prove to be inconsequential, and enable us to deepen our explanations of the phenomena of interest.
9 Conclusions

Throughout this report, classrooms have been conceptualized as socio-physical systems. These classroom systems contain actors, artifacts, and relationships that are potential resources, and it is through interacting with resources that students can learn. However, resources do not cause positive change simply by being present. Rather, the details of the student-teacher-resource relationships determine when and to what affect resources are used. Therefore, when considering the design and evaluation of a new educational innovation, it is imperative to capture and analyze data that points to the resources’ “fit” in socio-physical classroom systems. The purpose of this project was to describe the fit of resources in socio-physical classroom systems by describing the processes through which learning resources are enacted. In the following sections I’ll review the overarching research questions and motivations as well as the contributions made to the fields of Human-Computer Interaction and the Learning Sciences.

9.1 Review of research questions and motivations

The Scaling-Up SimCalc project provided treatment condition teachers and students with new educational resources for them to use. These resources included teacher professional development, curriculum, and an educational technology called SimCalc MathWorlds®. Both year one and year two study results indicated that students who had access to SimCalc resources performed better than their peers in control classrooms. However, from subsequent teacher phone-interviews, we found that teachers utilized the SimCalc MathWorlds with a variety of different technological set-ups: many went to school computer labs, some used mobile laptop cards, and a few used a single laptop connected to an overhead projector. The overarching goal for the current study was to determine how the different set-ups and implementations of SimCalc affected the enactment of resources in specific classrooms. This overarching motivation was then broken into three separate research questions, which are discussed below:

RQ1: How do different classrooms instantiate SimCalc?

In using the SimCalc resources and guiding their students through the SimCalc activities we see that the teachers in this study were acting within different environments with varying types and set-ups of physical resources. Furthermore, both the teachers and students accessed and used classroom resources in a variety of different ways. For example, the classrooms varied in their technological set-ups, the ways teachers presented the SimCalc MathWorlds to their students, the number of pages and lessons covered in the SimCalc student workbooks, and the frequency with which students engaged in discussions with their peers and teachers. The variety of observed resource interaction in these classrooms and the overall post-test gain scores point to the robustness of the SimCalc project: Students and teachers can interact with the SimCalc resources in a variety of ways and still achieve student-learning gains.

However, throughout the course of the SimCalc unit, the teachers and students established classroom practices for interacting with one another and negotiating the use and access to resources. These social-norms, or constellations of behavior surrounding resource use, were captured in five themes that emerged from a Grounded-Theory analysis of the case study data.
The five themes were: Resource Allocation and Student Roles and Responsibilities, Resource Modification and Movement, Attention Management, Assessing and Addressing Misunderstandings, and Perception and Framing of Student Resource Use. All of the themes represent and describe the social norms surrounding how teachers and students arranged, modified, attended to, interpreted, and valued resources.

**RQ2: What consequences does this have for student access to learning resources (of which computational technologies such as SimCalc MathWorlds are just one)?**

By comparing the five behavior themes to the literature on resource richness and teacher withitness, I was able to define two new theoretical constructs: socio-physical resource richness and resource use withitness. Socio-physical resource richness denotes the degree of physical and social access students have to resources in their classrooms. Resource use withitness denotes the strategies both teachers and students have for managing student access to and attention to resources. These constructs provide new mechanisms for describing (1) physical and social arrangements of resources and (2) teacher and student mechanisms for managing resource use. By describing the resource use withitness of students and teachers and the mutually constructed socio-physical resource richness of classrooms we provide explanations for how, when and why students accessed resources.

**RQ3: What are the possible effects on student learning and other outcomes?**

All of the students in the observed classrooms gained at least some knowledge on the mathematics of rate and proportionality (as indicated by their gain scores), and they gained this knowledge through the course of interacting with physical resources, peers, and their teacher. Indeed, the observation classrooms were selected so they varied on technological resource arrangements but had similar year-one average student gain scores. However, when we consider that students and teachers established social norms for negotiating resource use throughout the course of each class period, we see that these norms must have been mutually influenced by and/or developed in parallel to the students’ learning of mathematics. It is possible, what we see as successful learning of mathematics depended on the establishment of successful socio-technical norms. Successful socio-technical norms would be social norms that allow and even encourage students’ to access critical resources at the critical moments for learning. Also, when turn back to the discussion of socio-physical resource richness, we see that the different physical and social properties of resources had impact on other classroom factors, such as the overall classroom culture and the degree to which students interacted with technological resources specifically. This suggests that the physical and social arrangements of resources may have effects on other outcomes we care about, including students’ relationship to mathematics, their proficiency in using technology, their overall motivation, and their ability and inclination to become future knowledge workers.

### 9.2 Contributions

In this report, I have provided holistic accounts of the how, when, and why learning resources were enacted in specific case study classrooms. The case study classrooms were chosen for their variations in technological resource arrangements, and as such the case-study descriptions reflect
on how physical arrangements influenced the ways students and teachers interacted with learning resources. However, the case study classrooms also represent unique socio-physical systems in which processes, or social norms, for enacting learning resources are mutually constructed and negotiated by the teachers and students. These classroom systems with respect to resource use can be described at the classroom level, in terms of socio-physical resource richness, as well as at the individual actor level, in terms of resource use withitness. The case study descriptions and proposed theoretical constructs are important contributions to both the Learning Sciences and Human-Computer Interaction in that they illustrate (1) what is in the classroom socio-physical system, and (2) what are essential components of interpretations of the socio-physical system.

Researchers in the Learning Sciences endeavor to better understand classroom systems and the nature of student learning. From the case study descriptions and analysis I have presented here we can begin to examine: what classrooms look like when they have more, rather than less, socio-physical resource richness; how teachers and students interact when teachers have more, rather than less, resource use withitness; and how students can serve as resources for one another when there is a distribution of resource use withitness across the class. These new research pursuits in turn suggest that we (1) examine what investments, such as teacher training and resource funding, help create positive classroom environments in terms of resource use withitness and socio-physical resource richness, and (2) consider the affects of socio-physical resource rich classrooms and resource use “withit” teachers and students on outcomes such as students’ preparation for being future knowledge workers.

Designers and researchers in Human-Computer Interaction endeavor to better understand how new resource innovations can positively affect or change classrooms, teachers, and students. From the case study descriptions and analysis I have presented here, we can draw from concrete examples of learning resource enactments. That is, we can examine the methods students and teachers use to arrange, allocate, modify, move, attend to, interpret, and assign value to resources. This research pushes designers to incorporate the physical and social methods for learning resource enactments into educational resource designs. Furthermore, this research pushes those in HCI to consider their designs as a single part of larger classroom systems, systems that can be described in terms of socio-physical resource richness and resource use withitness.
References

2005, from http://www.ncrel.org/sdrs/areas/issues/content/cntareas/math/ma800.htm


### Appendix A – Initial Coding Scheme with Operational Definitions

<table>
<thead>
<tr>
<th>Code</th>
<th>Definition</th>
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</thead>
<tbody>
<tr>
<td><strong>Class Start Initiated</strong></td>
<td>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 (i.e. “Let’s take a seat.”). This may also include statements that serve as more passive directions intended to call students to order, such as, “Wow! It’s loud in here!”</td>
</tr>
<tr>
<td><strong>Class Start Actual</strong></td>
<td>The moment when the math instruction or activity begins. This is most often teacher initiated with directives like, “Open your books to page thirty-nine.” It can also happen with a student question or comment about something math related, such as homework, procedure, or concept. Sometimes a class starts immediately with students working because they received the directions in a prior class or are continuing work already in progress.</td>
</tr>
<tr>
<td><strong>Class End Initiated</strong></td>
<td>The moment when students begin preparations for finishing class. This may be initiated by the teacher with directives such as, “Log off your computers and close your books.” It may also be initiated by a bell ringing to signify the end of the period. Occasionally it is initiated by students, usually while working independently, who begin putting their materials away and preparing to leave class.</td>
</tr>
<tr>
<td><strong>Class End Actual</strong></td>
<td>The moment when students actually begin to leave the classroom. Usually they have logged off computers and packed up their materials. Often the teacher will initiate the exit of students from the classroom by giving permission to leave.</td>
</tr>
<tr>
<td><strong>Technology Student Initiated</strong></td>
<td>Any action taken by a student towards classroom technology, specifically computers and overhead projectors. Such actions may include using the technology or pointing at a screen. Also, any comment made by a student to direct attention towards classroom technology, such as, “Look at how fast I’ve made him run!” This does not necessarily include commentary about the technology or something seen on a screen, such as, “Wow! He’s fast.”</td>
</tr>
<tr>
<td><strong>Technology Teacher Initiated</strong></td>
<td>Any action taken by a teacher towards classroom technology or comment made to draw attention towards classroom technology. Frequently, this involves the teacher directing students to log on or off, or to open up and run a file.</td>
</tr>
<tr>
<td><strong>Technology Use Student Start</strong></td>
<td>The moment that students begin to use classroom technology, usually a computer. This moment is usually characterized by students logging in to a computer or opening a laptop. Applies to use of technology by more than one student (see Technology Teacher Use).</td>
</tr>
<tr>
<td><strong>Technology Use Student End</strong></td>
<td>Usually the moment when students finish their use of technology. This moment is usually characterized by students logging off or shutting down computers. This can also include prolonged periods of at least 15 minutes or more in which, despite being seated at a computer or having a laptop, technology is not being used.</td>
</tr>
</tbody>
</table>
open, students do not use the technology.

<p>| Technology Use Teacher Start | The moment that a teacher begins using classroom technology, such as a laptop or overhead projector. This may also include a teacher having a student use a laptop or projector at the continued command of the teacher with no access to the technology by the other students. One teacher (ID# 25211), for example, has students following along in their workbooks as she projects and runs the SimCalc simulations on a screen with the aid of a single student on a laptop. |
| Technology Use Teacher End | The moment a teacher finishes his or her use of technology. This moment is usually characterized by logging off or shutting down the technology. This can also include prolonged periods of at least 15 minutes when a teacher has not used or drawn attention to the technology. |
| Technology Delay Start | The moment class instruction or activity is halted due to a technology related issue, such as computers lacking the SimCalc program, or an error or glitch in the technology that renders it inoperable. Technology delays can also be concurrently coded as Instruction Interrupted if they, indeed, interrupt ongoing instruction. |
| Technology Delay End | The moment class instruction or activity resumes after a technology related issue is resolved. This is usually initiated by the teacher directing students to resume work or look at a problem currently in progress. |
| Discussion Whole Class | The inclusive vocal exchange of thoughts, ideas, instruction, and information by two or more individuals at the classroom-wide level. This usually means that all members of the class are intended to participate, whether actively by speaking or passively by listening. This may include periods in which the teacher is reading instructions aloud and students contribute questions or comments. Similarly, it may include periods when the students share answers aloud for the entire class to hear. More than one voice must be involved, whether invited or not. |
| Discussion Teacher-Student | The exclusive vocal exchange of thoughts, ideas, instruction, and information between the teacher and at least one student without the participation, passive or active, of the entire classroom. |
| Discussion Student-Student | The exclusive vocal exchange of thoughts, ideas, instruction, and information between at least two students without the participation, passive or active, of the entire classroom. This does not include unidirectional, vocal giving of answers, suggestions, or tips from one student to another or the solicitation of an answer or asking of a question in which no response is offered (see Miscellaneous Student Activity). Also, this code may be re-entered during a single, unbroken discussion when the topic changes drastically, such as when two students move on from discussing their answers to a problem to discussing an unrelated feature about a graph on a previous page. |
| Discussion Clarifying Procedure | A non-rhetorical, vocalized inquiry of a student about a procedure, such as the use of technology (“What is the step function again?”), workbook instructions (“Is it asking for one or two graphs?”), or teacher directions or expectations (“Were we supposed to do through page nine?”). |
| Math Instruction | When the teacher addresses the entire class with information about a |</p>
<table>
<thead>
<tr>
<th>Term</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Math Problem Start</td>
<td>The clear moment when a class, small group, or individual student begins a new problem in the workbook. This moment is most often initiated by specific mention of the new problem by a teacher or student. A math problem is defined as an entire section, or suite of smaller problems, in the workbook, such as “Run, Jace, Run” or “On the Road”, and work on the smaller components is not noted.</td>
</tr>
<tr>
<td>Math Problem End</td>
<td>The clear moment when a class, small group, or individual student finishes a problem in the workbook. This moment is most often initiated by specific mention of the work on the problem being terminated (not necessarily completed) by a teacher or student. A math problem is defined as an entire section, or suite of smaller problems, in the workbook, such as “Run, Jace, Run” or “On the Road”, and the smaller components are not noted.</td>
</tr>
<tr>
<td>Math Miscellaneous Student Activity</td>
<td>Any activity relating to the math work that cannot be coded in any other way. This may include students copying work from one another, or looking over at one another’s workbooks. It may also include the vocal or non-vocal offering or solicitation of answers or suggestions. It may also include the asking of question about a concept or answer without the offering of a response.</td>
</tr>
<tr>
<td>Instruction Interrupted</td>
<td>The moment when the classroom activity is halted to address a non-related or technical issue, such as when somebody enters the classroom and solicits the teacher’s attention while she is conducting a class-wide discussion and the students begin focusing their attention on non-class related matters. This also includes interruptions from school-wide announcements.</td>
</tr>
<tr>
<td>Instruction Resumed</td>
<td>The moment when the classroom activity begins again following an interruption due to a non-related or technical issue. This is usually characterized by the teacher calling the class back to attention or asking that they resume with the activity halted by the interruption.</td>
</tr>
<tr>
<td>Individual/Small Group Work</td>
<td>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. It does not include quicker moments of less than three minutes in which students fill in work either alone or with a neighbor while the entire class proceeds through the workbook together at the command of the teacher.</td>
</tr>
<tr>
<td>Workbook Teacher Mention</td>
<td>Any specific mention of or reference to the workbook by the teacher, whether directed to the entire class or a single student. This can include directives to open or close the workbook, to look at a certain page, or to notice a graph. It can also include instructions of which pages and/or problems to do. It can also include a directive to fill in something in the workbook.</td>
</tr>
</tbody>
</table>
| Workbook Student                        | When a student is observed in a specific action directed towards the
<table>
<thead>
<tr>
<th>Use</th>
<th>workbook, including writing, erasing, pointing at, or opening to a certain page. This does not include reading, either aloud or as inferred by body language.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Materials Teacher Reference</td>
<td>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. This can be related to acquisition or usage.</td>
</tr>
<tr>
<td>Materials Student Acquisition</td>
<td>Any time a student or students take, get up to fetch, or inquire about a non-computer item such as a calculator, colored pencil, or straight-edge or ruler.</td>
</tr>
<tr>
<td>Camera Noticing Student</td>
<td>Any time a student or group of students look at or talk about the camera or microphone. This may also include a student comment or student discussion about the camera or microphone or being recorded.</td>
</tr>
<tr>
<td>Camera Move</td>
<td>Any movement of the camera either intentionally or by accident. This includes panning the camera, zooming in or out, and shifting the whole apparatus to a new location.</td>
</tr>
<tr>
<td>Note</td>
<td>Any comment that the video reviewer makes pertaining to a feature, observation, or issue regarding the contents of a video. This may include points of note about student or teacher behavior, or it may be about decisions made regarding the transcription.</td>
</tr>
</tbody>
</table>
## Appendix B – Second-Round Coding Scheme with Operational Definitions

<table>
<thead>
<tr>
<th>Code</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physical Resources Properties and Arrangement</td>
<td>These codes are used to describe the classroom-to-classroom and group-to-group description of the physical resources properties and arrangements.</td>
</tr>
<tr>
<td>• Physical Resources Properties</td>
<td>Types of properties include the number and placement of laptops, rulers, calculators, pencils, workbooks, and other resources on the student desks and throughout the classroom.</td>
</tr>
<tr>
<td>• Rearrangement of Classroom and resources</td>
<td>Whenever resources, such as the student desks or laptops (and sometimes students themselves) are rearranged in the classroom space, this code is used.</td>
</tr>
<tr>
<td>◦ Student Rearrangement</td>
<td>Demarcates that a student did the resource rearrangement</td>
</tr>
<tr>
<td>◦ Teacher Rearrangement</td>
<td>Demarcates that a teacher did the resource rearrangement</td>
</tr>
<tr>
<td>Teacher Action and Arrangement</td>
<td>These codes describe where the teacher has positioned herself in the classroom space and any direction the teacher gives the students about classroom resources.</td>
</tr>
<tr>
<td>• Teacher at front of class</td>
<td>Indicates that the teacher has positioned herself at the front of the classroom space</td>
</tr>
<tr>
<td>• Teacher among students</td>
<td>Indicates that the teacher is positioned among student desks</td>
</tr>
<tr>
<td>• Teacher by teacher-desk</td>
<td>Indicates that the teacher is positioned behind or by the teacher-desk</td>
</tr>
<tr>
<td>• Teacher discussing resource use</td>
<td>This code was used to capture instances in which teachers discussed the appropriateness or inappropriateness of using certain resources. For instance, a teacher saying, “You don’t need to use the computer for this.”</td>
</tr>
<tr>
<td>Student Action and Arrangement</td>
<td>These codes describe how the students have arranged themselves in relation to the physical resources in the classroom and to other students.</td>
</tr>
<tr>
<td>• Resource show/give</td>
<td>When a student shows another student’s resources (such as their student workbook) or gives a resource to another student, this code is used.</td>
</tr>
<tr>
<td>• Resource look/take</td>
<td>When a student looks at or takes a resource from another student (such as a student workbook) this code is used.</td>
</tr>
<tr>
<td>• Conflict in resource arrangement</td>
<td>Indicates student-student conflict over resource use or arrangement</td>
</tr>
<tr>
<td>• Student-Student Help on</td>
<td>This code is used to demarcate a student giving help or...</td>
</tr>
<tr>
<td>Task</td>
<td>asking for help from another student</td>
</tr>
<tr>
<td>-------------------------------------------</td>
<td>---------------------------------------</td>
</tr>
<tr>
<td>• Student discussing resource use</td>
<td>This code was used to capture instances in which students discussed the appropriateness or inappropriateness of using certain resources. For instance, a student saying, “I don’t think we are supposed to use a calculator.”</td>
</tr>
</tbody>
</table>
# Appendix C – Table of SimCalc Workbook Units, Lessons, and Descriptions

<table>
<thead>
<tr>
<th>Workbook Unit Title</th>
<th>Pages</th>
<th>Day</th>
<th>Description</th>
<th>Lesson “Big Ideas” from SimCalc “Managing the Soccer Team” Unit Teacher Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Managing the Soccer Team</td>
<td>1 – 1</td>
<td></td>
<td>Student introduction to the unit and invitation to be the new soccer team manager. Teacher Notes: Designated as whole class discussion</td>
<td>Students connect a simulation of motion and its associated graph by understanding how time and distance are represented on the graph, and that each point on a line in the graph associates a time with a distance. (p. 1-A)</td>
</tr>
<tr>
<td>A Race Day</td>
<td>2 – 5</td>
<td>1</td>
<td>Student introduction to the SimCalc MathWorlds software. Also, students watch a simulation of a single runner’s motion and two runner’s motions. Teacher Notes: Designated as whole class discussion</td>
<td></td>
</tr>
<tr>
<td>Another Race Day</td>
<td>6 – 7</td>
<td></td>
<td>Students watch the motion of two runners and are asked to sketch a graphical representation of what they see. Teacher Notes: Designated as group work</td>
<td></td>
</tr>
<tr>
<td>Information-Quest</td>
<td>8 – 8</td>
<td></td>
<td>Students are asked to look up world facts about speeds, such as 100-meter dash records and average speed of a black ant. Teacher Notes: Designated as homework</td>
<td></td>
</tr>
<tr>
<td>Isabella Improves</td>
<td>9 – 11</td>
<td>2</td>
<td>Students sketch a graph and watch a simulation of one runner improving their time each week. They also tie the graphical representation to a data table. Teacher Notes: Designated as whole class discussion</td>
<td>For equal length dashes, as time goes down, the speed goes up. Faster dashers are represented by steeper lines (lines with greater slope). These connections are built through calculation and understand of the graph. (p. 9-A)</td>
</tr>
<tr>
<td>Faster than Max</td>
<td>12 – 13</td>
<td></td>
<td>Students are given a simulation and graphical representation for one runner</td>
<td></td>
</tr>
<tr>
<td>Practice Runs</td>
<td>14 – 18</td>
<td>(“Max”), and they are asked to draw the graphical representation of another runner (“Nola”) who they simply know was faster than Max. Teacher Notes: Designated as group work</td>
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<tr>
<td>Run, Jace, Run</td>
<td>19 – 21</td>
<td>Students are presented with four different graphs of two runners, and they are asked to determine who won the race in each of the graphs. They are also asked to draw graphs that match a simple description (such as, “ran 150 meters in 30 seconds”). Teacher Notes: Designated as homework</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Run, Jace, Run: Revisited</td>
<td>22 – 22</td>
<td>They use watch a SimCalc MathWorlds simulation of a runner and are asked to fill in a data table based on what they see and calculate the runner’s rate of motion. Teacher Notes: Designated as whole class discussion</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Back at the Office</td>
<td>23 – 25</td>
<td>Students are asked to match data tables to their corresponding graphs. Teacher Notes: Designated as group work/homework</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Slope and Rate</td>
<td>26 – 28</td>
<td>Students explore proportional relationships in a table of times and distances. Moving beyond just calculating the speed by dividing final position by final time, the associate the speed with each row in the table, and express this with a formula for the first time. They get a chance to practices this new connection. (p. 19-A)</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>Students extend the big idea from lesson 3-proportional quantities represented by formulas, graphs and table – to new contexts. Here the contexts are discrete, involving mostly number of items and cost. All the costs are units. (p. 23-A)</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>Students have discovered and used the idea that steeper lines indicate faster dashes; steeper lines indicate more expensive prices in</td>
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</tr>
<tr>
<td>Topic</td>
<td>Pages</td>
<td>Duration</td>
<td>Activity Description</td>
<td>Teacher Notes:</td>
</tr>
<tr>
<td>------------------------------</td>
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<td>----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
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<tr>
<td>or triangle method of</td>
<td></td>
<td></td>
<td>calculating slope. Teacher Notes: Designated as whole class discussion</td>
<td></td>
</tr>
<tr>
<td>distance/time and cost/amount graphs. This lesson helps them establish, quantitatively, that in such “accumulation graphs,” the slope of the line gives the rate of accumulation. Slope triangles are use. (p. 26-A)</td>
<td></td>
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</tr>
<tr>
<td>On The Road</td>
<td>29–32</td>
<td>6</td>
<td>Students are introduced to changing rates of motion via a simulation of a road trip involving a bus and a van. Teacher Notes: Designated as whole class discussion</td>
<td></td>
</tr>
<tr>
<td>Road Trip Records</td>
<td>33–36</td>
<td></td>
<td>Students are asked to represent a story about past road-trips into graphical form. The stories include rates, distances, and points in time where “obstacles” were encountered. Teacher Notes: Designated as group work</td>
<td>Using all they have learned so far, students investigate another motion context; miles per hour, buses and vans. Now each vehicle travels at different speeds during the same trip, so that the position graph is made of two or more line segments representing the different rates. (p. 29-A)</td>
</tr>
<tr>
<td>Graphs of Motion</td>
<td>27–40</td>
<td>7</td>
<td>Students are given stories about two runners in races and are asked to sketch the corresponding graph for each story. Teacher Notes: Designated as group work</td>
<td>This activity provides practice in motion contexts, including single and multiple rate motions, and coordination of graphs and stories. Students consolidate their learning by making 4 “model” graphs, stripping away particular contexts of runners or vehicles. (p. 37-A)</td>
</tr>
<tr>
<td>Salary Negotiations</td>
<td>41–41</td>
<td>8</td>
<td>Students are given scenarios for possible summer jobs with different pay rates. They are asked to calculate the rate of pay for each of the jobs. Teacher Notes: Designated as whole class discussion</td>
<td>Students explore multi-rate graphs in a non-motion context: dollars earned per hour. The same concepts of varying slopes and connections among words, graphs, and tables are used as in previous lessons. Problem solving is emphasized. (p. 41-A)</td>
</tr>
<tr>
<td>Summer Job Advice</td>
<td>42–47</td>
<td></td>
<td>The students are given different possible pay options for different types of jobs and asked to determine which would earn them the most amount of money. Also, the</td>
<td></td>
</tr>
<tr>
<td>All about MPG</td>
<td>48 – 49</td>
<td>Students are given a data table for the average MPG for several vehicles and asked to calculate the actual MPG for road trip scenarios. Teacher Notes: Designated as group work</td>
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</tr>
<tr>
<td>How Far on How Much? MPG</td>
<td>50 – 54</td>
<td>Students are given a table of gallons to distance with missing pieces of data. They are asked to calculate the MPG and fill in the missing pieces of the data table. They are also asked to graph the gallons to miles. Teacher Notes: Designated as homework</td>
<td></td>
<td></td>
</tr>
<tr>
<td>New contexts in which to use the concepts, skills, and techniques learned in the unit. (p. 50-A)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Suiting Up</td>
<td>55 – 56</td>
<td>Students are given the costs of new soccer uniforms where there are discounts given when bulk orders are made. They are asked to calculate the different rates for each range of uniforms purchased and to graph this relationship. Teacher Notes: Designated as group work</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Manager’s Report</td>
<td>57 - 58</td>
<td>Students are asked to fill out a memo on their experience as the soccer manager. In particular they are asked to reflect on the problems they encountered and how they solved those problems. Teacher Notes: Designated as group work</td>
<td></td>
<td></td>
</tr>
<tr>
<td>“Manager’s Report” allows students to report what they have learned within the overall context of the unit. “Mathematically Speaking” helps students connect mathematical vocabulary to the unit’s concepts.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mathematically Speaking</td>
<td>58 - 59</td>
<td>The students review the mathematical vocabulary they were introduced to throughout the unit. Teacher Notes: Designated as group work</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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Whole class discussion was suggested to be teacher led with at least one computer screen visible to all.

Group work was suggested to be students working in groups of 2 or 3 where each member of the group can see the shared computer screen, and the teacher circulates amongst the class groups.

Homework was suggested to as work students completed at home or individually during class time. For these activities, SimCalc MathWorlds was not needed.