INVESTIGATING VARIATION IN TEACHING WITH TECHNOLOGY-RICH INTERVENTION: WHAT MATTERS IN TEACHING AND TEACHER TRAINING AT SCALE?

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ABSTRACT OF THE DISSERTATION

Investigating Variation in Teaching with Technology-rich Intervention:

What Matters in Teaching and Teacher Training at Scale?

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A main question this dissertation addresses is: what variation in teaching and teacher training matter? This question is examined within a specific but important context: the scale-up of a technology-rich intervention focused on the algebra strand of 8^{th} grade mathematics.

I conducted a multi-level case study by gathering and analyzing data at all three levels of a train-the-trainer model of teacher professional development: from training of regional trainers, to teacher training, to classroom enactment. This case study was contextualized by a larger randomized experiment in the Scaling up SimCalc project. The larger project demonstrated the SimCalc intervention produced robust effects on student learning. Although treatment classrooms outperformed control classrooms, there was variation in student outcomes among teachers who used SimCalc. In the multi-level case studies, I sought to understand why two particular teachers had very different levels of

student outcomes. This puzzle was unraveled using a mixed methodology by first searching for distinctive features of their enactments that may have influenced student outcomes, and then looking for connections between these features and the teacher-training workshop attended.

Within this framework, the investigation provides arguments for these key findings:

1) Within the specific context of the SimCalc intervention, a wide variety of enactments may be acceptable and successful, provided a) the main ideas are presented accurately, b) students are given adequate time and c) students are given a reasonable amount of autonomy with the materials.
2) Assuming a robust intervention, there may be unexpected benefits in allowing teachers to enact materials within a comfort-zone of teaching that he/she finds effective in his/her classroom.
3) The training workshops were successful in broad goals, but less successful in communicating other more pedagogically-based goals to all teachers.

This dissertation is significant in that 1) it documents successful teaching practices in a prominent, successful scale-up experiment, 2) it investigates a complete “train-the-trainer” process, 3) it sheds light on the complex relationship between a teacher’s mathematical knowledge for teaching (MKT) and the quality of enacted instruction, and 4) it provides practical insight to trainers of short-term workshops, most notably: be realistic about what training can and cannot accomplish.

Acknowledgements

"It's the journey, not the destination."

This is something I repeated frequently when asked how soon I would complete my degree. Although it made light of the question, I didn't really say it in jest. I've taken "the scenic route" through this process, and I treasure all the experiences and especially all the people I have met along the way.

To my advisor, Roberta Schorr: Before I enrolled in the program, you listened to my thoughts and experiences and said: "You don't want a 2nd Master's degree. You want a doctorate." The idea first startled and then inspired me. When we re-connected as advisor/student, you probably didn't expect me to say: "I want to work with SimCalc," but I thank you for supporting that decision and making the connections to get me involved with the Scaling Up SimCalc project.

I also want to thank the rest of my committee. Each of you, along with Roberta, has offered me a unique perspective, and I believe the combination has been extraordinary in helping me to grow. To Stephen Hegedus and Jeremy Roschelle: You didn't expect a grad student from Rutgers to come knocking on your door, but both of you opened that door cheerfully and have offered me nothing but kind words and incredible advice and guidance. I thank you for your time and your willingness to share your experience and insight. To Alisa Belzer: as an "outsider" of both the SimCalc and math ed communities, you gave me different insights, some of which proved to be quite important. I thank you, too, for your time and willingness to share.

The best part of the Scaling Up SimCalc project is the people. The project members from SRI were especially helpful throughout this process, helping with

logistics, sharing data and offering important advice. Staff members of the Kaput Center at UMass were especially helpful during my early trips to Texas and with my first conference presentation. Project members from the participating universities (UMass Dartmouth, U of Texas at Austin, Virginia Tech) and also the Dana Center were always welcoming and encouraging during project meetings. I feel blessed to consider everyone involved my colleague and friend.

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Of course, my project would not have been possible without the TOT trainers, regional trainers, and the teachers who welcomed me into their workshops and classrooms, and took extra time to talk to me during interviews as well. Their talents and insights will remain with me and extend far beyond what I have written here.

I want to express my thanks to the MetroMath Center for the support I received as a MetroMath fellow, and the knowledge and experience I gained through MetroMath coursework and Affect Study research. I also want to thank all current and former Rutgers faculty members that I came to know and learn from, especially those involved in MetroMath and math education.

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Finally, I want to thank my family, who has been incredibly supportive throughout this journey. To my children, Laura and Jeff: during this journey I have watched you grow from young teenagers to promising young adults, both studying to be teachers yourself. I couldn't possibly be more proud of you. I'm so glad you share your journeys with me, and I suspect within a few years we'll be having discussions on the parallels between math education and music education.

To my husband Stan: you are my companion for all of life's journeys. After all these years, you're still the one. OK, you know I've got a 70's song playing in my head, don't you? You know me so well. Thanks for encouraging me down this particular road, and for being there for me in so many ways (including but not limited to tech-support!). You've listened, calmed me down at times, given me perspective, and loved me every step of the path. Our journey together has taken many unexpected turns through the years – recently we somehow landed in upstate New York – but I wouldn't trade the trip for anything.

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Chapter 1: Introduction

The heart of this dissertation focuses on a question that is easy to ask and difficult to answer: what variation in teaching and teacher training matter? This question is important because variation in teaching is both expected and a significant source of variation in student outcomes. All professions try to standardize practices to some degree in an effort to achieve consistently positive outcomes, and teacher professional education is no exception. Most teacher training tries to limit variation in teaching by encouraging some practices while discouraging others. But this process is unstable without deep knowledge of both 1) what types of teaching variation matter in student learning, and 2) what types of teacher behaviors can be effectively influenced by professional development.

Certainly, one dissertation cannot answer this question. The contribution of this work is to carefully examine the question within a certain specific but arguably important context: the scale-up of a technology-rich intervention focused on the algebra strand of 8th grade mathematics. Improving mathematics education in general is an important national goal with the transition into algebra considered especially important (National Mathematics Advisory Panel, 2008). We look to innovation to meet the challenge, and technology is frequently proposed as a piece of innovative approaches (Heid & Blume, 2008). Achievement gaps in particular are a great concern (National Center for Education Statistics, 2006), but in order to study gaps one must have a research project at sufficient scale to encounter the variation in populations, settings, and practices that may produce gaps.

The specific context of this work, the Scaling Up SimCalc project, enables and shapes the contribution in powerful ways through its particular foci. It focuses on the topic of linear functions in a manner geared toward more conceptually demanding mathematical tasks, incorporating concepts and skills beyond that typically taught in 8th grade. It also focuses on a particular technology (SimCalc MathWorlds®, from hereon referred to as SimCalc) which incorporates dynamic representations, a particularly promising approach in mathematics and science education (Kaput, 1992; Marzano, 1998). This deeper, broader curriculum and innovative use of technology opens up the range of possibility within student outcomes, and perhaps teacher variation as well. Furthermore, by staging the project in various regions in the large state of Texas, the project provides the means to study variation in enactments and outcomes that might be caused by diverse populations and settings.

Conducting my work within this specific context also limits generalizability; one cannot jump from what is true here to what might be true in other situations (different math focus, other technologies, other settings, etc.). But still, there is a great deal gained from being a small part within a larger context. I had the opportunity to collect and analyze my own data, while having access to a very rich set of additional data from the larger quantitative project.

In general, the larger study indicated that classrooms using the SimCalc intervention showed larger learning gains. But the size of these gains still varied from classroom to classroom, and my observations indicated clear variations in teacher enactments as well.

Thus, the larger project allowed me to ask a specific version of my main question: "What teaching practices seem to matter in increasing student achievement, specifically in the course of this technology-rich intervention in 8th grade pre-Algebra mathematics, and what features of teacher training appeared related to those teaching practices?" Herein lay an advantage of being linked to the larger quantitative project. While I was able to collect qualitative data concerning particular classrooms and trainings, I was also able to tap into the quantitative data for these classrooms, and describe these relative to the overall set of treatment and control classrooms. Most importantly, this included data on student achievement and teacher knowledge relative to the larger sample.

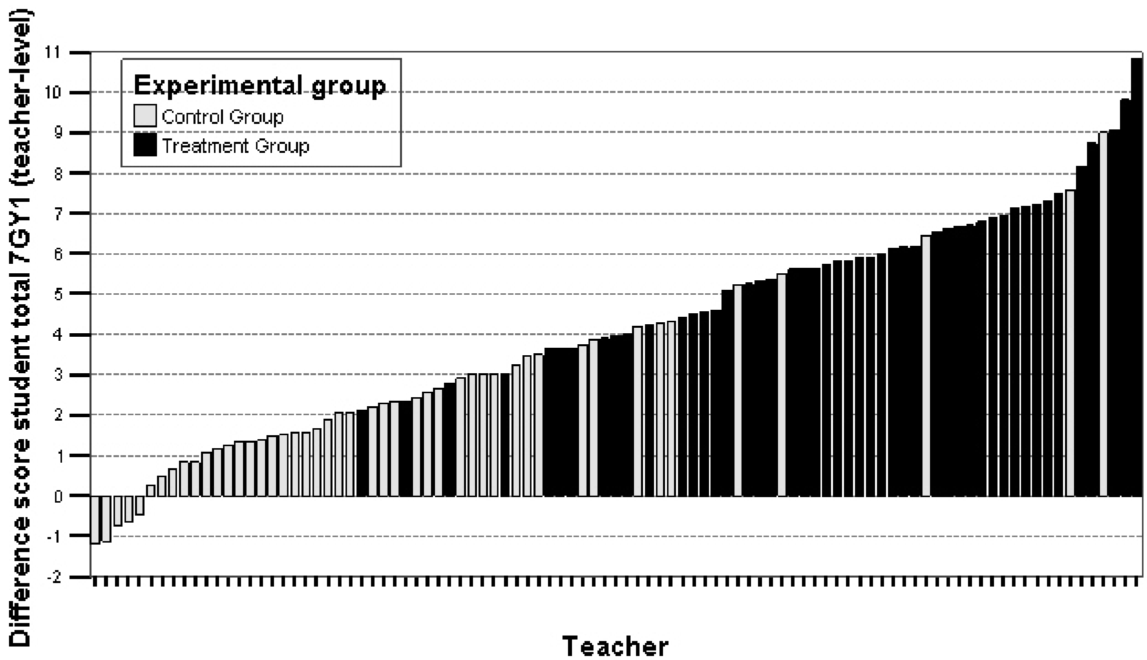
For this intervention, responsibility for teacher training was passed from the research team to Texas's conventional professional development model, in which the Dana Center (housed at the University of Texas at Austin) trains teacher-educators through a Training-of-Trainers (TOT) workshop, who then train teachers in their region. My unique opportunity and responsibility was to gather and analyze qualitative data from the overall project at all three levels of this train-the-trainer model. The TOT workshop, three of the regional teacher trainings, and seven classrooms involving eight participating teachers were observed and videotaped. All of these observed trainers and teachers were interviewed as well.

Thus, my investigation as a whole has the form of a multi-level case study contextualized by the larger randomized controlled experiment. This is a unique opportunity. Other studies I found in the literature that focused on the train-the-trainer model failed to follow the entire process, either providing qualitative analysis at just one level of training (Griffin, 1997) or just collecting data on the final classroom enactments

(Hahn, Noland, Rayens, & Christie, 2002) or measuring training impact through surveys or testing without performing case-study observations (Levy, Hirsch, Agababian, Segall, & Vanderschmidt, 1999; Wildy, Wallace, & Parker, 1996) . My multi-level design provides the opportunity to uncover connections between levels (TOT training, regional training, classroom teaching) not attainable through these other studies.

Three themes emerged in the course of my investigation, each related to an aspect of 'scaling up':

The most central theme of this investigation is the *interplay between robustness and variation*. The data of the larger project shows the intervention is robust, a very important characteristic at scale. This is indicated in both the 7^{th} grade experiment and the smaller 8^{th} grade portion, where my data set resides. Robustness means that variation in information such as SES, gender, student ability, teacher background, region of Texas, etc., did not significantly matter to the main effect. And yet, although most treatment classrooms had superior gain scores over the control group, there *were* differences in gains among the treatment classrooms, including among the treatment classrooms that I chose for my case-studies (see **Figure 1**). And so it is only natural to ask: why did some teachers obtain larger achievement gains while other teachers obtained smaller ones? Are variations in teacher practices a factor in these differences, and if so, what type of teacher practices seem to matter?



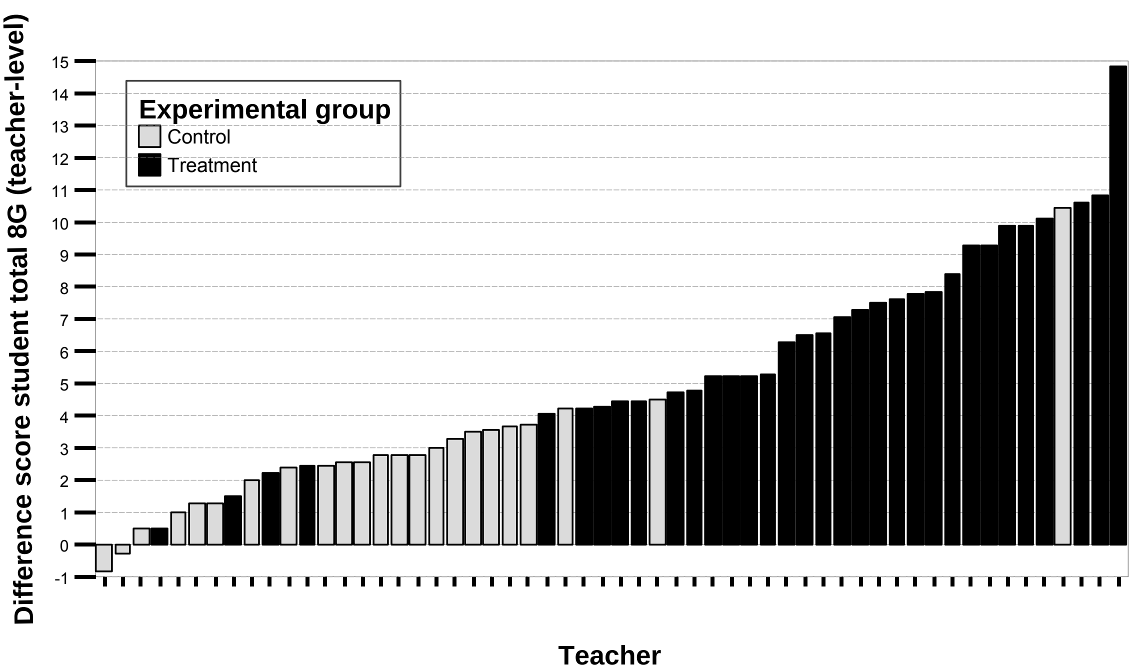


Figure 1: Gain scores from 1st year 7th grade (top) and 8th grade (bottom) studies

A secondary theme is the *interplay between implementation fidelity and reform ownership*. Implementation fidelity is a typical theme in scaling up research; a downfall of many efforts to scale up is not that the intervention doesn't work, but that teachers introduce adaptations that distort implementation such that benefits cannot be realized. And yet, in reality teachers adapt to local circumstances all the time – in fact this is a key feature of coming to own the reform or intervention. The key to resolving this tension lies in understanding what matters about variation. It may be fine to let some aspects of implementation vary, especially if the intervention is robust against these. But other types of variation may be destructive and therefore should be discouraged.

A third theme is the *connection between teacher training and teacher enactment* in a scale up experience. In a scale-up, it is often unfeasible to offer teacher professional development of extensive duration, so shorter term workshops prevail. This calls into question what can and should be accomplished in these trainings: Are there particular types of fidelity workshops can promote that will prove effective and provide enough commonality that the objectives of the intervention can be achieved? Are there other kinds of fidelity that really can only be accomplished through professional development of much longer duration and intensity? And finally, are there kinds of variation that don't matter in any significant way, so that for these aspects it would be reasonable to "let a thousand flowers bloom" while also encouraging a sense of personalization and ownership?

One possible approach to answering these questions is top down, starting from the theory of the SimCalc intervention, and then tracing that from trainer training to teacher training to classroom enactment. The rich variation observed in both workshop and classroom enactments discouraged me from starting from this vantage point, as I sensed I might miss something key. Instead, I chose a more grounded, bottom-up approach. Guiding this turn was the premise that variation in training is unimportant unless it makes a difference in the classroom.

Working from the bottom up, categorization of classroom events in terms of the SimCalc principles appeared to fall within a wide spectrum with no clear patterns. However, a contrast between the top-performing and the bottom-performing classrooms in my case-study sample (in terms of gain scores) led to a provocative puzzle. Marilyn, the teacher of the lowest performing classroom (gain scores remarkably low), was an experienced teacher with a class that did not stand out in any way within my case-study sample. Gayle, the teacher of the highest performing class, had a very low MKT score, indicating low mathematics knowledge for teaching, and was just a 2^{nd} year teacher. Gayle's class did not stand out within my sample either, except in terms of class-size; however, similar small classes within the larger study did not enjoy the same level of success. Furthermore, based on my classroom observations, the disparity in gain scores between Marilyn's and Gayle's classes took me by surprise.

This contrast in outcomes led to a new path of analysis. What variations between Marilyn's and Gayle's classroom enactments accounted for this marked difference in student outcomes? Since Marilyn and Gayle were from different regions of Texas, they had attended different workshops. Were training differences a factor?

To answer these questions, I used a mixed methodology considerably broader than a case study of two teachers. The puzzle was reconfigured into the following research questions:

1) What was distinctive about the enactments of these two teachers that may have been important factors in their class's post-unit test performance?
    a. What was distinctive about Marilyn's enactment, compared to the other case-study teachers, which might have been important factors in her class's poor performance?
    b. How did Gayle compare to Marilyn and the other case-study teachers in terms of the distinctive features established in (a)?
    c. What else was distinctive about Gayle's enactment compared to the other case-study teachers, which might have been important factors in her class's successful post-unit test performance?
2) Does there appear to be any relationship between these distinctive features of enactment and the teacher-training workshop attended?

The quantitative data available through the larger project was used to compare these teachers against my other case-study teachers, the larger treatment sample, and the control sample. Key quantitative features used were: class characteristics (especially class size, SES (using % free lunch as an indicator), and student pre- and post-test scores) and teacher characteristics (especially years of experience and MKT scores). The larger project also provided the teacher daily logs, which became an important aspect as I came to realize that time was an important piece of the puzzle. The daily logs gave me information on what transpired during the days when I was not observing.

It was my responsibility to collect the qualitative data for this study. Classroom and interview data was coded based upon a coding scheme to capture timing, teacher and student behaviors, and the role/use of the technology resource. This coding provided the basis for descriptive analysis and a quantitative classroom episode analysis. These codes were reviewed with another advanced doctoral student, and in many instances, disagreements were discussed and resolutions were achieved. Coding was ultimately restructured into a scheme that more clearly reflected the principles of SimCalc theory and methodology.

As previously stated, categorization of classroom events in terms of the SimCalc principles appeared to fall within a wide spectrum with no clear patterns. Therefore a different analysis was needed in order to uncover distinctive features of Marilyn's and Gayle's enactments. This in fact was accomplished by taking a broader rather than a deeper view. Certain aspects of Marilyn's enactment obviously stood out, behaviors not observed in the other case-study classrooms. These obvious distinctions led my attention to four categories of variation which were then systematically examined across my sample of teachers. These categories were:

1) *Time*: the amount of time spent on each lesson and the unit as a whole
2) *Materials*: the amount of workbook materials (activities) covered
3) *Organization*: how the teachers organized class time, broken into the categories of reviewing, introducing activities, allowing students to work on activities, and conducting follow-up discussions
4) *Level of directive teaching*: how teachers directed student work, e.g., activities were done a specific way together as a class, or students were given explicit instructions or formulas, or teacher gave students autonomy in deciding an approach.

First Marilyn, and then Gayle, was compared across my entire sample to determine how her enactment was distinctive within these categories. The details of the categorizations developed more fully as I moved from Marilyn to Gayle. Once distinctive features of enactment were isolated, I moved on to a cross-level analysis to try to find pre-cursors to these features. For instance, once I established that Marilyn spent considerably less time on the unit than other case-study teachers, I examined data to see how timing issues had been discussed during the TOT and teacher workshops

Within this framework of four categories of variation, my dissertation will present and argue for the following key findings:

1) Within the specific context of the SimCalc intervention, a wide variety of enactments may be acceptable and successful, provided a) the main ideas are presented accurately, b) students are given adequate time and c) students are given a reasonable amount of autonomy with the materials.
2) It is not easy to predict which teachers or which teaching practices will result in the best student outcomes. Many kinds of variation not planned by the SimCalc designers may be beneficial. A few kinds of variation, however, are clearly not beneficial.
3) All the training workshops were successful in providing the case-study teachers with familiarity and comfort with the software and materials. They also seemed to sufficiently emphasize the "big ideas" of the unit, since all case-study teachers were observed to bring these ideas into their classroom.

4) Many additional goals of the trainers were not successfully communicated from trainer to teacher. At times, a subset of that modeled by the trainer was brought back into the classroom, somewhat skewing the trainer's original intent. These goals may not be reasonable objectives for a short term workshop approach.

This dissertation is significant on many academic fronts. First, it documents what was successful in terms of teaching practices in a prominent, successful scale-up experiment. As I was the sole researcher collecting case-study data on the 8^{th} grade portion of the SimCalc project, it is the only source of information within the project that studies this success within the context of multi-tiered training. It is also unique and valuable in that it investigates a complete "train-the-trainer" chain of influences, from TOT training through to the classroom. This is rarely done despite the prominence of the model. Furthermore, this dissertation sheds light on the complex relationship between a teacher's mathematical knowledge for teaching and the quality of his/her enacted instruction. Although these two are frequently considered to go hand-in-hand, this work helps substantiate other pieces of the equation. Finally, my work highlights issues relating to implementation fidelity within scaling up research. It may be there is simply no one "right" way to enact materials that will adequately resonate within the constraints of every teacher's understanding, especially with only short-term teacher training. Assuming a robust intervention, this research demonstrates there may be unexpected benefits in providing structured but non-scripted materials and trainings which allow teachers to enact the intervention within a comfort-zone of teaching that he/she finds effective in his/her classroom.

This work is significant on many practical fronts as well. Workshop trainers might take from this work certain key ideas and practices. Once again, assuming a robust intervention, this work would argue against striving for cookie-cutter enactments (i.e. over-scripting). What it argues *for* is that trainers of short-term workshops be realistic about training and stick to the simplest, broadest objectives. Teachers should be given adequate time during the workshop to get familiar and comfortable with the materials. It appears instrumental to provide teachers with the "big ideas" of the curriculum, to discuss how to pace the activities (so that adequate time is allotted), and to help teachers decide which parts of the unit are essential and what can be skipped if necessary. On the other hand, pedagogical change is unlikely; while regional trainers may wish to emphasize pedagogical best practices, at least some teachers may be focusing on more superficial features. In the context of a technology-rich intervention, trainers might need to stress the importance of students using the software themselves *without being explicitly led through the work*, and the importance of subsequent follow-up discussions. Trainer modeling does not appear to be a sufficient way to relay these ideas. In fact, "modeling" how to use the software productively may be particularly important but opaque to some teachers and require more explication.

This dissertation is divided into 9 chapters. Chapters 2-3 contain the necessary background information in terms of literature review and research design/methodology. I introduce all eight of my case-study teachers in Chapter 4. At the beginning of this chapter, Marilyn and Gayle are simply two of the pack, but at the end I describe how they were chosen as special foci. Chapter 5 concentrates on Marilyn, isolating and describing how her enactment was distinctive within the categories of *time, material, class* *organization and level of directive teaching,* and including a detailed description of Marilyn's enactment of lesson 5. Chapter 6 continues with a concentration on Gayle, first describing how Gayle compared within my sample with respect to the four categories, and then describing motivation for, and carrying out, a deeper analysis. As with Marilyn, Gayle's chapter includes a detailed description of her enactment of lesson 5. Chapter 7 then describes the TOT workshop and the training workshops attended by Marilyn and Gayle, focusing specifically on the four categories of distinction, and also describing the regional trainer's enactment of the lesson 5 materials. My focus on lesson 5 allowed me to compare specific enactments across teachers *and* across trainers, and also, perhaps most importantly, to find specific connections *between* levels. Chapter 8 discusses Marilyn and Gayle individually, describing apparent links and disconnects to their training experiences and providing an analysis. Subsequently, the chapter also discusses noted contrasts between the two regional trainings, pointing out what variation seemed to have an impact on classroom enactments and what did not. Finally, Chapter 9 boils everything down to a set of conclusions and suggestions for future research.

Chapter 2: Literature Review

In order to study at-scale variation in teacher training and teacher practice within the context of this project, three areas of literature are important: 1) literature about the SimCalc software itself and the history and design of the Scaling Up SimCalc Project in particular; 2) literature on scale-up and teacher training in the context of scale-up, with particular emphasis on the train-the-trainer method; 3) literature on technology and teachers, most importantly the affordances of technology like SimCalc, aspects of teacher practice which might affect student access to and the effectiveness of these technological affordances, and how teacher training might affect these teacher practices.

2.1 SimCalc MathWorlds®

SimCalc can be described as representationally innovative technology, situated in a genre of software called “dynamic mathematics”. Such technologies provide a variety of dynamic, linked representations (including algebraic symbols, graphs, tables, and geometric figures), to simulations, allowing students to reason while directly and dynamically editing and working with representations and corresponding simulated phenomena (Hegedus, 2007).

SimCalc supports the creation and modification of functions as well as providing the means to simulate motion based on these functions. The SimCalc environment links graphical, tabular and algebraic representations, through simulations, which students can algebraically or graphically edit, thus providing the student opportunity to investigate how changes in one representation impact other representations, and encouraging an integrated understanding (Kaput & Schorr, 2007). This exploratory environment would be difficult to enact with ordinary static classroom materials. The importance of multi-representations in mathematics, and particularly in the understanding of functions, is well-documented (Goldin & Kaput, 1996; NCTM, 2000). The ability to identify and represent a concept in different representational forms and the ability to translate between these forms is necessary for mastering the concept (Goldin & Shteingold, 2001; Lesh, Post, & Behr, 1987). However, when these connections are not emphasized in the classroom, students often compartmentalize the different representations of a concept, treating each as distinct (Elia & Gagatsis, 2007).

Within the SimCalc environment, the goal is to have learning occur as the activities increase the student's attention to the mathematically important aspects of the system, especially when students can observe differences between their expectations and the how the dynamic system actually behaves (Tatar et al., 2008). Members of the research team describe the important characteristics of the overall approach as follows (Roschelle, Tatar, Shechtman, & Knudsen, 2008, p. 154):

> Hallmarks of the SimCalc approach to the mathematics of change and variation are:
>
> 1. Anchoring students' efforts to make sense of complex mathematics in their experience of familiar motions, which are portrayed as computer animations.
> 2. Engaging students in activities in which they make and analyze graphs that control animations.
> 3. Introducing piecewise linear functions as models of everyday situations with changing rates.
> 4. Connecting students' mathematical understanding of rate and proportionality across key mathematical representations (algebraic expressions, tables, graphs) and familiar representations (narrative stories and animations of motion).
> 5. Structuring pedagogy around a cycle that asks students to make predictions, compare their predictions to mathematical reality, and explain any differences.
> 6. Integrating curriculum, software, and teacher professional development as mutually supporting elements of implementation.

The SimCalc software and its underlying approach has had consistently positive pre-to-post results at various grade-levels (middle school through college) in various small-scale studies around the country, including projects in disadvantaged locations such as Newark and some of the most poorly performing sections of Massachusetts (Schorr, 2003). Still, this success suffered from the “boutique critique”(Tatar et al., 2008) which states “Sure, it works in this special setting”, since the researchers came into the school setting and had control over many aspects of the intervention.

2.1.1 The Scaling Up SimCalc Project

The Scaling Up SimCalc project moves beyond these many small scale successes to study the innovation under scale-up conditions, where its use is no longer limited to a small group of highly trained teachers but extends to a wide variety of teachers in a wide variety of settings. The project was designed to study an *integrated system* including the SimCalc software, as described below.

Using the framework provided by Cohen and colleagues (Cohen, Raudenbush, & Ball, 2003), the Scaling Up SimCalc project takes a systems view of the classroom, defining instruction as “the interaction among teachers and students around content, in environments” (see **Figure 2**). Their research logic has been to seek improvement to this system in the form of integrated curriculum, software, and professional development. Each piece of the integrated system is essential; the pieces are not meant to be considered or evaluated separately (Tatar et al., 2008).

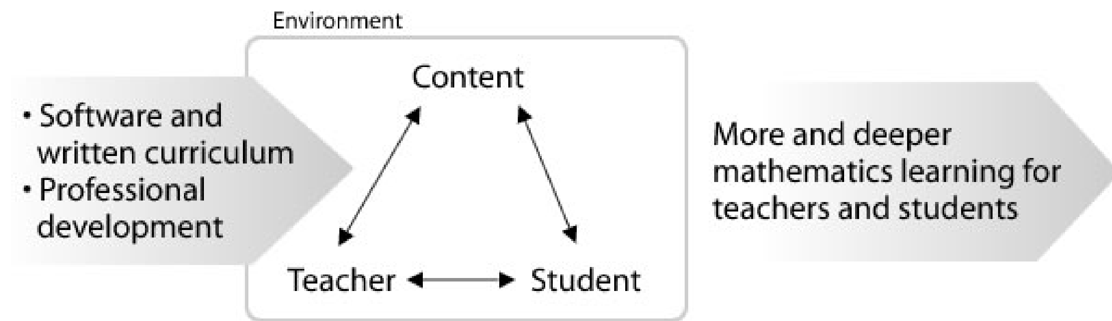


Figure 2: Intervention logic (Tatar et al., 2008)

A replacement unit strategy was adopted, a decision based on the literature (see for example, Cohen & Hill, 2001) and because it is easier to garner district consent for a relatively small intervention, compared to a more extensive one. Furthermore, this approach limits curricular ambition (Cohen & Ball, 1999), without watering down the ambitious content of the unit itself.

In a pilot study, a 3-week replacement unit was designed and implemented in 7th grade classrooms in the state of Texas. These classrooms used the SimCalc software, a workbook for students, and corresponding teacher's guide designed for ease of use by teachers with limited training. The questions and activities in the workbook provided structure without dictating scripted procedures. The teacher's guide provided information on the mathematical goals of each activity as well as an answer key.

The SimCalc research team had few precedents for the amount and type of professional development to provide to teachers for this sort of scale-up endeavor (Tatar et al., 2008). Ultimately, teacher training was limited to a multi-day workshop with minimal pedagogical dictates. Teachers were not instructed, nor were they observed, to make major changes to their teaching practices, although they were advised to use a variety of instructional modes, from whole class discussion to small group and individual work.

This pilot was a stepping stone to the present SimCalc Scale-up project, which has two separate pieces: a 3-year 7th grade study, similar but larger than the pilot, and a one-year 8th grade study. The 8th grade portion is similar in style (a 3-week replacement unit with similar design characteristics), but with a curriculum focusing on rate and linear function rather than the 7th grade topics of rate and proportionality, and a different method of professional development (employing the train-the-trainer model).

The project developed its own student assessments (one for 7th, one for 8th grade), and a test of Mathematical Knowledge for Teaching to be administered to the teachers, all designed to satisfy rigorous reliability and validation standards (Roschelle et al., under review; Shechtman et al., 2009). Further details can be found in the methodology section.

Because the Scaling Up SimCalc project provides only short-term teacher training with no expectation of major changes in teacher practices, the positive results from the pilot and ongoing study put into question certain assumptions related to representationally innovative technologies: in contrast to the usual assumptions about teacher development, they indicate the potential to make strides in student learning through the use of the innovation without extensive teacher professional development or a shift to a learner-centered form of pedagogy. If this is indeed the case, this opens a wider path to innovation adoption. Innovators may be able to make an earlier, more immediate impact on a wider audience in the short term, at the same time setting a credible base of improvement that can then serve longer-term growth (Tatar et al., 2008).

2.1.2 Summary

The SimCalc software is representationally innovative technology and supports a learning environment where activities increase student's attention to the mathematically important aspects of a dynamic system of functions and simulated motion. The Scaling Up SimCalc project seeks to study the innovation under scale-up conditions. This project views the classroom as an integrated system of interactions among teachers, students, and content/resources, and seeks improvement to the system through integrated curriculum, software, and teacher professional development. With few precedents for the amount and type of professional development to provide for such an endeavor, teacher training was ultimately limited to a multi-day workshop with minimal pedagogical dictates. In contrast to the usual assumptions about teacher development, the positive results from the pilot and ongoing study indicate the potential to make strides in student learning through the use of the innovation without extensive teacher professional development or a shift to a learner-centered form of pedagogy.

2.2 Scale-up

Research on scale-up in any category of education is limited (Adler, Ball, Krainer, Lin, & Novotna, 2005; Denton, Vaughn, & Fletcher, 2003; Tatar et al., 2008). The knowledge base that does exist is largely anecdotal (Denton, Vaughn, & Fletcher, 2003). And yet, issues of scale are important for many reasons. It is important to policy makers, who may be reluctant to support innovations that have only been tested in a few places. It is also important to district supervisors and administrators who are concerned whether the innovation will generalize to the specifics of their setting. Questions about the benefits of an innovation deployed at scale are especially important in the educational context of the United States due to its extensive size and its distributed control over curriculum and policy (Tatar et al., 2008). Researchers in various fields of education agree that the knowledge base on scaling up research-validated innovations needs to be expanded. Studies are needed to examine what happens when programs spread to multiple sites, what works, what goes wrong, and what do designers need to know and think about within this context (Adler, Ball, Krainer, Lin, & Novotna, 2005). It is especially important to have a research base on how to impact actual classroom practice (Fletcher, Foorman, Denton, & Vaughn, 2006).

A distinction can be made between researching the effects of scale up and researching the process of scale up. Fletcher and colleagues (2006) specifically lament the lack of research on the latter:

> As yet there has been little emphasis on scaling as a topic in educational research. In fact, there is often a disconnect between the research that might occur in a laboratory or a school and its widespread implementation. There seems to be a middle step that is missing, which is research on what it would take to scale a particular intervention. (p. 57)

Most existing educational research defines scale in quantitative terms, such as the number of schools reached by a reform effort. However, a different definition can focus attention on alternative indicators of the processes and outcomes of scale. Coburn suggests a conceptualization of scale that attends to four specific and interrelated dimensions: depth, sustainability, spread, and shift in reform ownership (Coburn, 2003). There is substantial research indicating a difference between the intended curriculum and enacted curriculum (Stein, Remillard, & Smith, 2007; Zbiek & Hollebrands, 2008), and thus Coburn stresses the importance of looking beyond the presence or absence of specific material and tasks when investigating scale-up, and to focus instead on how teachers engage students with these materials and tasks. A shift in reform ownership becomes important as a reform spreads and the need for professional development and technical assistance grows beyond the capacity of the reform/research team.

The Scaling Up SimCalc project addresses some of researcher's concerns and expands on the conceptualization of scale, with an emphasis on providing evidence that scaling up SimCalc is both possible and desirable (Tatar et al., 2008). Within this framework, the project identifies the assessment of *robustness* as a key contribution of scaling up research. Robustness is defined as the "consistency of the innovation's benefits for student learning when deployed consistently to a wide variety of students, teachers, and setting" (Roschelle, Tatar, Shechtman, & Knudsen, 2008, p. 151).

2.2.1 Professional Development and Training at Scale

As this sub-study progressed, it became necessary to distinguish between the terms *teacher professional development* and *teacher training.* Almost all literature on teacher learning uses the term *professional development*. Most often, this refers to long-term or on-going experiences aimed at deep-rooted changes in teacher's content knowledge, beliefs, and/or practices. The Scaling Up SimCalc project, however, offered what the research team commonly called *training*: a short-term experience with a specific focus and short-range goals. In order to understand what might be possible in the short-term versus the long-term, research on both professional development and training is relevant to this study.

Borko (2004) surveyed the field of teacher professional development (PD) research, organizing the evaluated programs into three phases: Phase 1 research activities study an individual professional development program at a single site; Phase 2 looks at a single professional development program enacted by more than one facilitator at more than one site; and Phase 3 compares multiple professional development programs. Most professional development research to date is Phase 1 research, which "provides evidence that intensive professional development programs can help teachers to increase their knowledge and change their instructional practices" (p. 5).

Borko's review is clearly focused on professional development research as opposed to training. She clearly states that *intensive* professional development can help change teacher's practices, and there is no indication that short-term training could generate similar results. However, her observations and conclusions about Phase 2 research, where the PD program expands to multiple facilitators at multiple sites, may be relevant to scaled up training programs: the central goal of Phase 2 research is to determine if the program can be enacted with *integrity* especially as it becomes more and more removed from the original professional development providers. Integrity does not imply a rigid implementation of required activities; rather, it is important to investigate the balance and tradeoffs between fidelity and adaptation, and to identify the critical elements of the program that must be maintained in order to ensure coherence to its crucial goals and principles.

The train-the-trainer model is used extensively in a wide variety of fields for both professional development and for shorter term training situations. It is sometimes referred to as "Training-of-Trainers" (often abbreviated as TOT or ToT), and both terms are used interchangeably in this paper. The model is attractive to a scale-up project as it is an economic means for spread and also sustainability as it allows researchers to turn responsibility over to established, trusted community leaders. Peer-leaders rather than professional adult-educators are often employed as the trainers when using this model. Despite its prevalence, there is little information in the literature concerning the validity of this method in any discipline (Orfaly et al., 2005). Although not a validity study, the efforts in this paper to report on links and/or disconnects between teacher training and teacher enactment within a specific implementation of the train-the-trainer model will provide validity information.

Although the train-the-trainer method has the potential for dilution or lack of fidelity, studies exist that demonstrate this is not necessarily the case. In the field of Public Health, an emergency preparedness program that used the train-the trainer model showed consistent learning gains (measured by pre- and post-tests) across trainers and participants (Levy, Hirsch, Agababian, Segall, & Vanderschmidt, 1999).

Two reportedly successfully scaled programs for beginning reading, *Reading Recovery* and *Success For All,* both employ a train-the-trainer format in which trainers from a central institution not only provide initial training to teacher leaders or facilitators within a school district, but also maintain a relationship with these leaders/facilitators as they train district teachers and monitor their implementations (Denton, Vaughn, & Fletcher, 2003; Fletcher, Foorman, Denton, & Vaughn, 2006). Thus, in this version of the train-the-trainer model, provisions were made for on-going mentoring and support at both levels of training.

Similar on-going multi-level mentoring also existed in a study set up to investigate the train-the-trainer model in the field of remedial and special education. The training was designed for General Education Intervention teams and consisted of a number of sessions conducted over an entire school year. Some teams were trained directly by university-based staff, while other teams received training from employees in their district, who prepared for this task by attending specialized training from the university staff. Analysis based on survey information indicated no significant difference between the two sets of teams. In this study, the university staff not only conducted occasional consultation visits with district trainers throughout the year, but also carefully monitored and assisted these trainers while they delivered their district trainings (Bahr et al., 2006).

The Yale Child Study Center School Development Program (SDP) also reported considerable scale up success using a version of the train-the-trainer model (Comer & Joyner, 2006). Once trained by SDP staff, the mid-level trainers served as an instructor and on-going coach at the district level while receiving continuing support from SDP staff through coaching and consultation. The School Development Program takes a multi-pronged systemic approach to school improvement, involving "representatives from all the stake-holders – parents, teachers, central office administrators, board members, and principals" (p. 163). There is additional training for some stakeholders that is not part of the train-the-trainer model but is provided directly at Yale.

Not all implementations of the train-the-trainer model report success. In describing on-going progress in the Texas Reading Initiative, dependence on the train-the-trainer model was cited as a major problem (Fletcher, Foorman, Denton, & Vaughn, 2006). Materials developed for this initiative were described as generic and the train-the-trainer model was believed to magnify this generic nature and thus dilute the impact of the intervention. In-class follow-up coaching was considered a solution to this problem, but was found to be difficult to achieve. Comparing this experience with the previous examples suggests successful on-going support may be required with this training method when long-term behavioral changes are desired. Furthermore, it may be that generic materials will be ineffectual at scale. Borko (2004) recommends that Phase 2 professional development be well defined and clearly specified, effectively communicating to the facilitators the intended goals and uses of the resources.

Some train-the-trainer studies report success with limitations, which may provide insights into the potential for the method in the context of short-term training. One study (Hahn, Noland, Rayens, & Christie, 2002) evaluated a substance abuse prevention curriculum that employed the train-the-trainer model. The program provided short term training (at both levels) but implementation in the classroom extended over three years (15 sessions the first year, 10 then next, 5 the third year). Fidelity measurements were conducted during classroom enactments (not the training sessions). The study reported reasonably high content fidelity, but somewhat less fidelity in terms of process: the two least used methods of instruction were those that made the program unique. Furthermore, ratings of implementation efficacy were lower for some of the more innovative aspects of the intervention, including one element considered essential.

This result suggests that short-term training via the train-the-trainer method may be sufficient for content transfer, but insufficient for learning to confidently implement innovative teaching techniques. Similar findings were found in self-reports from a 2-year longitudinal case-study in Western Australia (Wildy, Wallace, & Parker, 1996). This study followed the process as ‘link-teachers’ were trained to provide in-service training to their peers after attending a training session themselves on a physics syllabus reform. The research reported that link teachers found the training to be adequate for understanding the new syllabus, and left them with a reasonable comfort level for disseminating the philosophy and strategies of the curriculum, but less comfortable actually modeling them. The teachers found the training useful in understanding the new philosophy, but less useful in helping them to understand the new teaching techniques and assessment strategies.

Finally, in the field of applied psychology, (Hinds, Patterson, & Pfeffer, 2001) found that non-expert trainers may actually be better at knowledge transfer than their expert counterparts. Compared to non-expert trainers, experts were found to convey information at a more abstract level and to provide fewer concrete statements in their instruction, failing to take into account the novice's lack of domain knowledge. It is interesting to consider the interplay between experts and novices in the context of the train-the-trainer model and the Scaling Up SimCalc project in particular. While the research team could be considered experts, the mid-level regional trainers are novices in terms of the SimCalc approach, but perhaps experts in terms of pedagogy, mathematics knowledge and/or mathematics knowledge for teaching compared to at least some participant teachers.

2.2.2 Summary

There is agreement within many fields of education that research on scale-up is limited and needs to be expanded, especially research on the process of scaling up. One suggested conceptualization of scale is to attend to four dimensions: depth, sustainability, spread, and shift in reform ownership. The Scaling Up SimCalc expands on the conceptualization of scale, identifying the assessment of *robustness* (the consistency of the innovation's benefits) as a key contribution of scaling up research.

A shift in reform ownership becomes important as the need for professional development grows beyond the capacity of the research team, as is modeled in this project with its use of multi-level training. This shift links this project with Borko's review of Phase 2 PD research. In the Scaling Up SimCalc project as with more extensive PD programs, as training expands to multiple sites and facilitators, it is important to investigate the balance and tradeoffs between fidelity and adaptation, and to identify the critical elements of the program that must be maintained.

The literature includes several reports of successfully scaled programs that used the train-the-trainer model, although not all programs using the model reported success. Two implications of the literature are that the train-the-trainer method may be sufficient for content transfer but changes in teaching techniques may require on-going support, and that generic materials may be ineffectual at scale. The Scaling Up SimCalc project provided specific materials (in the form of a unit workbook and teacher's guide) and did not strive for or expect teacher pedagogical change. Another study found that expert trainers sometimes fail to take into account a novice's lack of domain knowledge and need for concrete examples; this is potentially relevant at both but especially at the 2nd training level (trainer-teacher) of the train-the-trainer model.

2.3 Teachers and Technology

2.3.1 Technology affordances

No technology has made as wide an impact on classroom teaching as the use of hand-held calculators. Not only are graphing calculators in prevalent use but their use has also changed achievement levels (Ellington, 2004), although only when integrated with changes in teaching and practice (Roschelle & Gallagher, 2005).

There are potentials both *while* working with the graphing calculator as well as those that come *as a result* of this work. The *amplification metaphor* suggests the graphing calculator amplifies the zone of proximal development (ZPD) by eliminating tedious and time-consuming tasks, leaving more room in the zone for conceptually demanding tasks and thus allowing the user to solve problems more easily and efficiently. Other effects may happen *as a consequence* of using the technology, helping the student use concepts in deeper and perhaps innovative ways. These *cognitive re-organization effects* may result in long-term changes in the quality of learning (Berger, 1998).

Although calculators are the first ubiquitous form of classroom technology, many of its affordances are applicable to SimCalc and similar software. Certainly, SimCalc facilitates some of the tedious tasks of graph and table generation. Furthermore, SimCalc is a member of a new generation of software with the potential for cognitive re-organization effects. The Geometer's Sketchpad (Jackiw, 1991, 2001), Tinkerplots (Konold, in press), and Fathom (Finzer, 2005) as well as SimCalc, provide new representational infrastructures (Kaput, 1994; Kaput & Schorr, 2007) that make use of the visual, dynamic, and interactional properties of the computational medium (Tatar et al., 2008), and can play an important role in rich learning environments. For instance, Tinkerplots, a software tool for teaching data analysis, provides tools allowing students to build both typical statistical displays and their own original representations. This allows the students, not the software, to have ultimate control of what is produced, and in the process to become explicitly aware of the important principles involved (Konold, in press).

There is evidence that technology can encourage collaborative inquiry in both small groups and whole class discussion (Goos, Galbraith, Renshaw, & Geiger, 2003) and that socio-mathematical norms can emerge not only from verbal interactions but also from computer manipulations as a method of non-verbal communication (Hershkowitz & Schwarz, 1999). Multi-representational software may also trigger conceptual change as students develop metaphors and construct shared meanings (Roschelle, 1992).

2.3.2 Teachers, the Critical Link

With its short-term training approach, the SimCalc Scale-up project was not designed to "shake up teacher beliefs" or significantly alter teacher behavior, which most likely would require long-term professional development. There is therefore very little in the professional development literature (with its emphasis on reform teaching methods) to indicate what specific factors to look for as likely important features of a SimCalc classroom. Furthermore, most research concerned with incorporating mathematics technology into classroom practice reports outcomes without describing classroom events or teacher actions and roles within the classroom technological environment (Zbiek & Hollebrands, 2008), and so this area of literature is also a limited resource.

Just what happened in almost every treatment classroom that could account for the documented student learning gains? The research team theorizes the source of leverage is in the interaction between students and the technology and related materials. However, no curriculum is self-enacting; in fact, "the enacted curriculum is co-constructed by teachers and students in a particular context" (Stein, Remillard, & Smith, 2007). In order for students to interact with these materials appropriately, they must be given the opportunity to do so. Herein lays a crucial role for the teacher: *Does the teacher make these opportunities available?* Cohen and Ball state:

> Teachers' knowledge, experience, and skills affect the interactions of students and materials in ways that neither students nor materials can. That is because teachers mediate instruction: their interpretation of educational materials affects curriculum potential and use, and their understanding of students affects students' opportunities to learn (Cohen & Ball, 1999, p. 4).

Teachers are invariably important mediators in the classroom, and thus there is reason to believe they are in fact the gatekeepers to students' productive use of the software and materials. With this in mind, it is important to consider how teachers might organize instruction, both in terms of teaching approach and lesson structure.

In this short-term training situation, teachers are unlikely to have significantly changed their usual teaching approach. Kuhs & Ball (1986) describe four dominant approaches to teaching mathematics:

1. *Learner-focused*: mathematics teaching that focuses on the learner's personal construction of mathematical knowledge
2. *Content-focused with an emphasis on conceptual understanding:* mathematics teaching that is driven by the content itself but emphasizes conceptual understanding
3. *Content-focused with an emphasis on performance:* mathematics teaching that emphasizes student performance and mastery of mathematical rules and procedures; and
4. *Classroom-focused:* mathematics teaching based on knowledge about effective classrooms. (p. 2)

Differences between the four approaches are most easily identified by considering what governs the instruction. Advocates of a constructivist viewpoint typically adhere to the learner-focused classroom, in which the learner is the focus of classroom activity. In approaches #2 and #3, the content is the focus of classroom activity, with the teacher maintaining a particular view of the content and concepts that students are to learn. If there is an emphasis on conceptual understanding (#2), the teacher believes, as in the learner-centered approach, that meaningful learning requires the student construct their own understanding of the material. If there is an emphasis on performance (#3), completing textbook exercises and test questions accurately is the focal point of instruction. Finally, in the classroom-focused approach, instructional effectiveness is considered a function of classroom efficiency and organization.

Teachers often structure lessons by segmenting them into portions that serve different pedagogical and cognitive purposes. The TIMSS 1999 Video Study (Hiebert et al., 2003) reported on the organizational environment of mathematics classrooms, stating that organization can affect both content and teaching approach. One structural aspect studied was the organization of old and new material. Three categories were identified and defined: *reviewing, introducing new content,* and *practicing new content.* The study discusses *reviewing* segments in the following manner: "This category, more technically called 'addressing content introduced in previous lessons', focused on the review or reinforcement of content presented previously" (p. 49). *Introducing new content* segments were described: "This category focused on introducing content that students had not worked on in an earlier lesson" (p. 49). *Practicing new content* included all time spent on "practicing and applying content introduced in the current lesson", including "the follow-up discussion of an idea or formula after the class engaged in some practice or application" (p. 49-50).

Another structural aspect focused on in the study was the distinction between public and private classroom interaction. Again, the study states that teacher decisions related to this aspect can either enable or constrain the learning environment. They define *public interaction* as "public presentation by teacher or one or more students intended for all students" (p. 53). *Private interaction* is defined as "All students work at their seats, either individually, in pairs, or in small groups, while the teacher often circulates around the room and interacts privately with individual students" (p. 54). The study also defined three other categories: *optional, student presents information* **(**other students may listen or continue working independently**),** *optional, teacher presents information* **(**again, students may attend or continue independent work**),** and *mixed private and public work* (some students working privately while others work publicly with the teacher).

Teachers can play many productive roles in a classroom using technology (Zbiek & Hollebrands, 2008). Teacher behavior, particularly encouraging interpretation and explanation, seem to influence students' development of varied and effective technology usage (Doerr & Zangor, 2000). But studies have also uncovered common teacher practices that can adversely affect student learning with technology. Sometimes teachers fixate on teaching the *technology*, rather than teaching *with* the technology (Zbiek & Hollebrands, 2008). Another common practice (not limited to technology interventions) is that of 'funneling' in which the teacher invokes interactive patterns that are specifically aimed toward student's direct declaration of the expected answer. Rather than facilitating, funneling questions tend to hinder student exploration, reasoning, and conceptual understanding (Steinbring, 1992). Another study reported a teacher tendency to ignore curriculum documentation (Sarama, Clements, & Henry, 1998).

Teachers also have various perceptions about the role technology can play (Ruthven & Hennessy, 2002; Sarama, Clements, & Henry, 1998), which may be connected to teachers' instructional philosophy and lead to instructional differences that impact student learning (Slavit and Yeidel, 1999). For instance, one study found that a deficit of mathematical knowledge and a belief that computer activities were fun "add-ons" hampered teachers' successful implementation of the innovation. (Sarama, Clements, & Henry, 1998).

Still, variation itself cannot necessarily be categorized as either favorable or adverse. Berger applies Wertsch's concept of *privileging* (1991) to the mathematical educational environment to describe how classroom norms affect students' choice of mental function (and thus solution method):

> Rather, it is the social setting and values which may elevate one form of mental functioning over another and in this way privilege a particular form of mental operation such as algebraic or graphical reasoning. In fact, for the last two centuries algebra has been privileged …as the most appropriate mode of mathematical discourse … (Berger, 1998).

The effects of privileging were observed in a study involving three teachers who assisted researchers in designing a 20-lesson introductory calculus program that used a Computer Algebra System (CAS). Despite the fact the curriculum was jointly created, they found that each teacher gave priority to different conceptual tasks. Although overall student performance was comparable between the classes, when test items were looked at individually, it became clear that each class had different cognitive experiences and acquired different conceptual understandings and a different set of competencies (Kendal & Stacey, 2001).

Finally, it is important to consider the role of teacher knowledge when examining how teachers might influence student's opportunities to learn. There is a great deal of research linking teacher knowledge and student achievement (Hill, Rowan, & Ball, 2005). This is an important issue in a scale-up situation with short-term training, since such training is unlikely to substantially improve the overall knowledge base of individual teachers. How disadvantaged, then, are teachers with lower mathematical knowledge for teaching? Within the Scaling Up SimCalc project, results of the first year 7th grade study indicated a small but significant correlation between mathematical knowledge for teaching (MKT) and student gains, but there was no significant correlation observed in the 8th grade or second-year 7th grade study (Shechtman et al., 2009).

In a recent exploratory study, Hill and colleagues (Hill et al., 2008) acknowledge the strong connection between MKT and what they termed teacher mathematical quality of instruction (MQI), but also discovered certain factors that potentially mediate this connection, either impeding or improving the quality of instruction depending on circumstance. For instance, the study found the use of supplemental activities and materials often lowered the quality of mathematical instruction, even sometimes in the case of teachers with higher MKT. Furthermore, the study reported on a focus teacher, Rebecca, whose MQI was described as significantly better than what one would expect by considering her MKT score. The proposed explanation was that although Rebecca's teaching was most often procedural in nature and contained frequent errors, 1) she did not attempt to teach "conceptually" oriented mathematics and thus her errors were perhaps less damaging than other teacher's conceptual mistakes, 2) she kept her class on-task and focused on the mathematics, leaving students proficient in specific procedures; and 3) she strictly followed the textbook, which alleviated problems sometimes caused by inventive but ineffectual application of supplementary materials.

Rebecca therefore is a case in point of a teacher with low MKT providing mathematics instruction of reasonable quality despite certain limitations. The Scaling Up SimCalc project considered the possibility of such occurrences: one of the predictions of the overall project was that the “strongest” teachers and sites (in terms of high SES, well prepared students, experienced teachers, etc.) would best use the materials, but students of the “weakest” teachers and sites (low SES, less experienced teachers, etc.) would benefit the most from the clarity of the intervention and the depth of student experiences (Roschelle, Tatar, & Kaput, 2008). In other words, the benefits of the intervention might be achieved in a variety of ways, depending on teacher strengths and classroom situation.

2.3.2.1 Professional development/training and teacher behavior

Despite professional development efforts, teachers have difficulty making real changes to the core of their mathematics instruction and often have misperceptions about the intentions of reform curriculum and measures (Firestone, Schorr, & Monfils, 2004). It is well documented that teacher’s self-reports can differ greatly from actual classroom enactments (Firestone, Schorr, & Monfils, 2004; Judson, 2006; Stein, Remillard, & Smith, 2007). One study observed and interviewed a sampling of 25 teachers from six different districts, all of whom had participated in professional development activities and self-reported that their teaching was aligned with reform practices (Spillane, 1999). The study found evidence of surface features of reform ideas but concluded that only four of these teachers had made significant changes to the core of their practice:

> While they gravitated to key reform themes, such as problem solving, most of the teachers we investigated did not understand these themes as representing ideas about changing the core of their mathematics instruction. Thus, they enacted reform ideas in ways that involved few, or no, changes to the core of their practice. Moreover, they were convinced

> that their enactment of the reforms was consistent with reformers' proposals. (p. 170)

Hill and colleagues report on the success and failure of professional development:

> Professional development, unfortunately, cut both ways … In some cases, our evidence suggests that extensive professional development served to bolster teachers' knowledge and improve the mathematical quality of instruction. But we also saw countless examples of "new" mathematical methods and activities arriving in classrooms courtesy of the professional development institutes teachers attended, and then being implemented without meaning, or even without purpose. (Hill et al., 2008, p. 500)

Other studies have documented the limited effects of training and professional development, particularly in the context of a technology innovation. One study (Sarama, Clements, & Henry, 1998) described how the designers and support staff believed they were modeling a philosophical stance, pedagogical approach, activities, and software tools while the teachers only saw a model of the latter two. Slavit and Yeidel (1999) found teacher philosophy more influential than mentoring; in a study of two teachers using a technology innovation, the unmentored teacher with a philosophy more compatible to activity goals than the mentored teacher made more appropriate use of the activities, despite this lack of mentoring.

Similar training limitations have already been documented in the Scaling Up SimCalc project as well. For instance, phone interviews of teachers involved in the first-year 7th grade portion of the project revealed that, despite training sessions emphasizing student predictions and simulations, only a small number of teachers felt it was important for their students to manipulate the SimCalc software themselves rather than simply watch the teacher demonstrate with an overhead projector (Tatar & Dickey-Kurdziolek, 2007).

Because of teachers' strong influence in the classroom, Slavit and Yeidel (1999) recommend that the goals of the technology intervention be well-connected to those of the instructor and students in order to be effective. Zbiek and Hollebrands (2008) make further recommendations: strong professional development, in their opinion, would give teachers continued support and time to play, get acquainted with the software as a personal tool, work with activities involving students' technology-based work, try out the software with small groups of students before trying it with an entire class, and experience activities that involve mathematically valid but surprising technology results. They also see a need to help teachers learn to facilitate post-technology discussions.

And finally, Hill and colleagues recommend professional development strongly linked to children's learning:

> What is essential is a model in which teachers' learning is anchored in the real work of instruction, with the content demands and children's learning placed front and center as the driving force of professional development. This proposal departs from current models of professional development in this country, by addressing content learning for teachers in the context of children's learning (Hill et al., 2008, p. 501).

2.3.3 Summary

SimCalc's visual, dynamic, and interactional properties can play an important role in rich learning environments. In fact, the Scaling Up SimCalc research team theorizes that the consistently positive learning gains experienced in the treatment classrooms was due in large part to the interaction between students and the technology/materials. And yet, teachers are important mediators and may be gatekeepers to these resources. It is thus important to consider how teachers might organize instruction, and whether organizational differences might impact learning gains. It is also important to consider how teachers are trained and what teacher behaviors might be influenced by this training.

Features such as teacher approach, structural aspects of how class time is organized (both in terms material and whole group vs. individual/small group work), and the means of focusing on the technology, perhaps even privileging certain conceptual tasks over others, are all important factors that affect how the software and material is made available to the students, and thus may be factors in student outcomes.

The larger project found no significant correlation in the 8th grade study between teacher MKT and student gains. This somewhat surprising result is also encouraging, in that teachers with lower MKT are not necessarily disadvantaged with these materials. In a study by Hill and colleagues, the description of a certain teacher (Rebecca) suggests that other teacher qualities might offset a weakness in mathematical knowledge for teaching.

Teachers have difficulty making real changes in their practice, especially in the context of technology, despite professional development efforts. Often, only surface features of reforms are enacted. Studies provide various recommendations for strong professional development, some specifically focused on a technology-rich environment. While the Scaling Up SimCalc project does not expect nor strive for significant change in teacher practice, its design follows some of these recommendations, such as giving teachers time to play and get acquainted with the software as a personal tool, and to work with activities involving student's technology-based work. Also, by centering workshop experiences on the student materials and activities of the intervention, the project links the training to children's learning, as Hill and colleagues suggest.

Chapter 3: Design and Methodology

3.1 Setting

This research examines the 8th grade portion of the SimCalc Scale-up project, a controlled randomized trial involving 56 teachers and over 800 students. In this portion of the project, SimCalc software was used in combination with a 3-week replacement curriculum unit for 8th graders in the state of Texas. The replacement unit focused on rate and linear functions, and included mathematics typically addressed in 8th grade (referred to as M1 items) and mathematics beyond that typically addressed in 8th grade (referred to as M2 items). The core mathematical constructs of the unit are detailed in Appendix A. Target classes were randomly assigned: each participating teacher in both the treatment and control samples was given a random number corresponding to the class period in which he/she was to teach the materials.

For this intervention, responsibility for teacher training was passed from the research team to Texas's conventional professional development model, in which the Dana Center (housed at the University of Texas at Austin) trains teacher-educators through a Training-of-Trainers (TOT) workshop, who then train teachers in their region.

Six teacher-educators from five different regions of Texas attended the 2-day TOT workshop in May of 2006. Each of these participants then returned to their home region and, at some later date, facilitated a 3-day summer workshop for teachers participating in this study. These teachers then implemented the SimCalc unit within their normal classroom practice, at a time of their own choosing, during the 2006-2007 school year.

This situation provided the opportunity to investigate all levels of the 3-stage train-the-trainer model of professional development, specifically within the context of a technology-rich innovation.

3.2 Data Collection

As this will be a qualitative study, data collection focused on interview and observation techniques. During workshop observations, the role of this researcher took on that of an observer and partial participant (Patton, 1987), as the teacher-educators and teachers included the researcher in conversations occasionally during sessions and frequently during break-times. These conversations were general in nature and simply served to establish a comfortable rapport between participants and researcher. The researcher took on a more formal on-looker role during actual classroom observations. This distinction came about naturally rather than intentionally. In all instances, the participants were made fully aware of the researcher's purpose as an observer for this study.

Interviews for this study were semi-structured in design, allowing a somewhat conversational style and the potential to pursue information if a useful topic spontaneously occurred, while still maintaining a level of consistency among the interviews.

All data collection was performed by this researcher with the assistance of two trained graduate students, who took turns accompanying the researcher and were responsible for videotaping while this researcher took field notes. Starting with the first level, the 2-day Training-of-Trainer (TOT) workshop was observed and videotaped. The primary facilitator of this workshop was also the primary author of the curriculum materials. This facilitator was interviewed both before and after the workshop (protocol in Appendix C), and participating teacher-educators answered short journal-type questions each day, focusing on what they believed to be the day's most important ideas and issues (journal questions in Appendix D).

Three of the five 3-day teacher workshops, conducted by the teacher-educators who had attended the TOT, were then observed and videotaped. Again, the facilitators were interviewed (protocol in Appendix E) and the participants were asked to answer short journal-type questions (Appendix F). We limited research to three workshops for practical reasons: of the two workshops not observed, one had only one confirmed participant and the other was conducted over a time period conflicting with two of the other workshops; furthermore the workshop facilitator did not wish to be videotaped (for personal reasons not related to the study).

At least two teachers from each region were then selected for classroom observation. Facilitator information about the teachers, as well as teacher responses to the end-of-day journal questions, was considered to construct a short list of possible teachers to select; the final choice was based on simple availability. Three of the selected teachers were 2nd-year teachers (two of these worked together in the same classroom), while the other five were more experienced (teacher experience is listed in ***Table* 3** of Chapter 4). Further detail concerning teacher selection is provided in the section describing the case study teachers.

Each selected teacher's classroom was scheduled to be observed and videotaped for three days, during the period(s) the teacher enacted the intervention. Over the course of the project, as this researcher traveled from teacher to teacher, data was collected on lessons spanning the majority of the 10-lesson curriculum unit, which provides a broad perspective on implementation variation. Lessons 4-6 were observed most often; in fact all teachers were observed teaching at least one of these three lessons.

Certain exceptions to the observation plans occurred due to uncontrollable circumstances. (In order to protect privacy, all teacher names and any student names used in this report are pseudo-names.) Carly's final day was cancelled due to the unexpected death of a vice-principal. However, Carly taught the target class for two 40-minute periods per day, and thus data had already been collected from the first period of Day 1 and both periods of Day 2, thus providing an adequate amount of data for analysis. In the case of Jackie and Samuel (who taught together), although interviews were completed, observation data is limited. The first day was cancelled due to an administrative error, and only half of the final day was observed due to a major highway accident resulting in the observers arriving mid-session. Thus, Jackie and Samuel are included in this study when appropriate, and omitted when data is insufficient.

The teachers were interviewed before the start of observations, and when possible, interviews continued at the end of each daily observation to discuss the day's events. Every teacher also participated in a post-observation interview, which included questions about overall experiences with the unit. In general, interviews were ½ to 1 hour in length. The interview protocol (Appendix G) was semi-structured and focused on the teacher's perceptions of the Math goals, how s/he planned to use the technology to achieve these goals, and his/her perception of the actual classroom implementation.

One hand-held video-camera was used for all videotaping (as described below). A videographer and an observer (this author) taking field-notes were both present for the

TOT workshop and the teacher workshops. For classroom observations, when a separate videographer was not available, the observer took notes as possible while operating the camera, prioritizing the collection of video data as a non-participant observer. During the teacher workshops, the camera followed the teacher-educator as he/she facilitated and interacted with the participants; similarly in the classroom, the camera followed the teacher. For the TOT workshop, precedence was given to the facilitators, but often focused on paired groups of teacher-educators as well.

Teachers also attended a 1-day planning day workshop later that summer, in which they were given time to actually plan out their lessons. This researcher observed and videotaped these workshops in two of the three regions of this study (Region A and Region C).

In Region A, the workshop facilitator went to each teacher's classroom one day during the course of implementation to offer feedback and support. This facilitator offered to accompany me for one day as I went in for classroom observations with two of her teachers, including Marilyn, who became a focus for this study. Video was taken of her post-observation debriefing with these teachers, and the facilitator was later interviewed to gather her overall assessment of the teachers' implementation of the unit, based on the training provided.

In addition to data collected for this study, the larger project has provided the following information on each selected teacher:

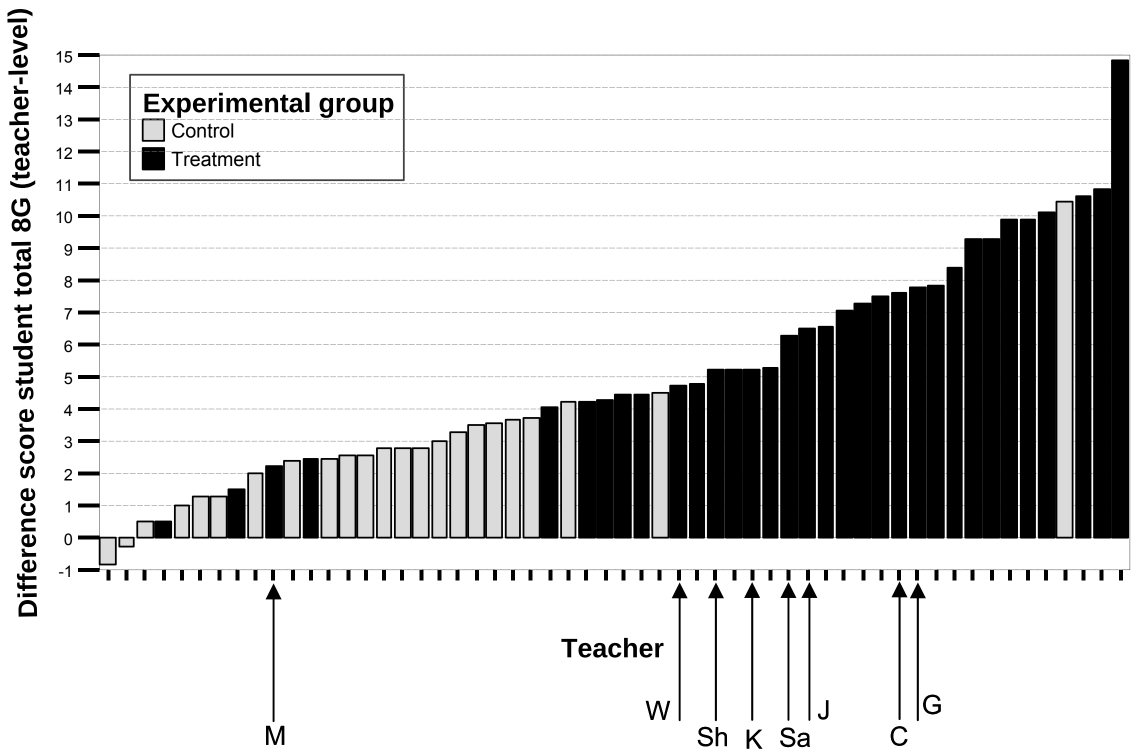
1. Educational background
2. Certification
3. Years teaching (FT/PT)

4. Years teaching mathematics (FT/PT)
5. Teacher self-report logs
   a. Pre-unit log describing characteristics of the target class and general classroom environment
   b. Daily log describing daily activity with the intervention
   c. Post-unit log describing decisions made during implementation and the teacher's overall experiences and opinions of the unit
6. Student pre- and post-test scores of the target class
7. Pre- and post- teacher scores on a Mathematics Knowledge for Teaching MKT) test (administered before attending the workshop and then again after teaching the unit).

Student pre- and post-test scores (item #6) were the scores from the assessment administered by the larger project. The assessment was developed specifically for this project to ensure its design captured the depth of conceptual understanding students could attain with the SimCalc materials. Rigorous validation standards were upheld (Roschelle et al., under review). After first establishing a conceptual assessment framework and assessment blueprint, a pool of assessment items were developed drawing from both standardized tests and original written-from-scratch items. The items were validated and refined via expert panel review, student cognitive think-aloud exercises (to eliminate or revise ambiguous or ineffective questions), and field testing. Finally, a summative expert panel review provided further feedback. The assessment, consisting of 36 questions (18 M1 questions, 18 M2 questions) was administered to the students as both a pre- and post- test.

An assessment to measure teacher Mathematical Knowledge for Teaching (item #7) was also developed with rigorous standards for validity and reliability using an Evidence-Centered Design approach (Shechtman et al., 2009). Domain modeling and analysis was used to build a framework and establish specifications, which led to a conceptual assessment framework defining the types and properties of assessment items. Using this framework, task development entailed an iterative cycle of developing, refining, analyzing validity, further refining, and possibly developing new items. Empirical methods used to gather proof of validity included field testing with a large sample, cognitive think-alouds, and summative expert panel review.

The larger project also provided quantitative information on overall comparative results that informed the analytical methodology. **Figure 3** displays the histogram of mean gains by classroom for the 8th grade study, with arrows denoting the case-study teachers for this research.



Arrows denote teachers in this study, table denotes teachers and workshop region

Teacher	**Workshop Region**
M: Marilyn	Region A
W: Wendy	Region A
Sh: Sharon	Region B
K: Kate	Region A
Sa: Samuel	Region C *(combined class with Jackie)*
J: Jackie	Region C
C: Carly	Region C
G: Gayle	Region B

Figure 3: Mean gains by classroom

3.3 Analytical Methodology

The software package NVivo was used for data storage and analysis. Interviews were transcribed, and the videotapes of the training workshops and classroom observations were logged in the following fashion: the activities on the tape were described, focusing the descriptions on both dialogue and behaviors that relate to the mathematics and the use of the technology and curriculum materials. This logging process included time-stamps at least every 5 minutes, including a time-stamp whenever the class or workshop began whole-class discussions, whenever individual or group-work commenced, and whenever a new idea or task was introduced.

3.3.1 Classroom Data

Classroom video and teacher interview data was coded based upon a coding scheme to capture timing (see episode definitions in next section), teacher and student behaviors, and the role/use of the technology resource. This coding process, which evolved as the analysis continued, provided the researcher with knowledge of the classroom data and provided the basis for descriptive analysis. These codes were reviewed with another advanced doctoral student, and in many instances, disagreements were discussed and resolutions were achieved.

Interview codes captured teachers discussing the mathematics of the intervention, time constraints issues, pedagogical decisions, the teacher's perception of the role of the technology resource, his/her perception of whether or not their implementation was aligned with the designers' expectations, and other reflective and descriptive comments.

Classroom video teacher codes captured teacher behaviors such as encouraging justification and alternative answers/solution methods, addressing confusion, providing information, and asking “What if” questions, and also behaviors such as explicitly providing reasoning (rather than allowing students to reason themselves), giving explicit directions on how to solve a problem (rather than acknowledging that multiple solution methods exist), and working out a problem together before allowing students time to attempt the work themselves.

Student behavior captured on camera was noted, but since the one available camera followed the teacher, student information is limited and incomplete and therefore used only sparingly in the descriptive analysis.

Use of the technology resource was initially coded to capture both its method of use and the purpose of its use within the current activity. The methods of use were defined as dynamic (running or ‘step’ing through a simulation), static (looking at or using a static screen of information), manipulative (e.g., changing the graph, the axes, or the starting point of a character; opening a window, moving the cursor, etc.), or tech talk (use of technology resource is discussed or referenced). Coded purposes included demonstration, making/testing/discussing a conjecture, comparing graphs, determining rate of motion, gathering one-dimensional information (such as distance traveled, time elapsed, etc.), connecting representations (motion/graph/table/equation/verbal), and connecting ideas between problems or lessons.

Coding was ultimately restructured into a scheme that more clearly reflected the principles of SimCalc theory and methodology. The following fundamental SimCalc principles were used:

1. To create a dynamic interactive representational environment (2 or more representations being attended to at the same time through the technology resource)
2. The use of visually editable graphs
3. The ability to create experiences in the classroom with dynamic linked representations as an access route to understand and interpret formal math representations.
4. Formalisms are introduced to help consolidate and extend knowledge established previously. (y = mx+b, proportionality, linearity)
5. The use of piecewise graphs to describe piece-wise motion/variation
6. The ability to use, have, or operate with quick iterative feedback cycles

Classroom events were categorized in terms of which of the above principles the event enacted. This further analysis revealed that, in terms of the SimCalc principles, categorization of classroom events and teacher behaviors appeared to fall within a wide spectrum with no clear patterns.

Two teachers, however, stood out as interesting cases based on the aforementioned preliminary analysis combined with results from the overall project: one due to unfavorable gain scores and the other due to favorable gain scores. Thus, these teachers were chosen for a more in-depth analysis, focusing attention on what made these particular teachers distinctive within the case-study sample. Specific details regarding the selection of these teachers will be described below.

The histogram of classroom mean gains (Figure 3) indicated that in general, classrooms in the treatment group out-performed those in the control group. The first teacher selected for in-depth analysis, Marilyn, taught the one classroom selected for this sub-study that failed to follow this rule. Analysis entailed looking specifically for distinctive features of Marilyn's classroom versus the other case-study classrooms to provide insight into which aspects of enactment might be crucial for an adequately successful implementation of the SimCalc intervention.

“Success”, of course, is difficult to define. Test scores are the main measure of success available for this study. The case-study classrooms represent a wide variety of student abilities from a high-achieving class of Algebra I students to a class made up entirely of low-achieving students, many of whom were mainstreamed special education and/or LEP/ESL (Limited English Proficiency/English as a Second Language) learners. Of course, the overall treatment group has as much if not even more diversity in abilities. Thus gain scores are a better indication of comparative success than raw scores, and are used as such throughout this sub-study. An “adequately successful” treatment enactment will defined as an enactment in which classroom-level average gain scores were higher than 85% of the control group, which would categorize all but four of the treatment classes as adequately successful, and place Marilyn’s enactment far outside this category.

In terms of future enactments, the intent would be to strive for “adequately successful” enactments in which students learn as much and likely more than they would if, as in the case of the control group classrooms, other currently typical materials were used instead of the SimCalc resources.

Based on mean gains, none of the selected classrooms reached the very highest levels of achievement, and thus no classroom was selected as an exemplar of outstanding success. However, the most successful class in this study (based on these mean gains) was taught by a 2nd-year teacher with a low MKT score who focused the students on formulas and procedures to a greater extent than observed in the other case-study classrooms. This class's favorable gain scores may be considered somewhat surprising, especially given the literature base suggesting that MKT may be linked to student performance. On the other hand, this is potentially encouraging from the standpoint of scale-up, in that it may provide evidence that teachers with reportedly low MKT can also experience success with the materials with only short-term training. Thus, this teacher (Gayle) was also selected for in-depth analysis.

This analysis started by first looking at features deemed potentially crucial for adequate implementation (based on the analysis of Marilyn, the first focus teacher), and then continued by searching for distinctive features of this particular teacher versus the other case-study teachers, to identify possible strengths in approach that might have been a factor in these comparatively strong gain scores. "Distinctive", as it is used in the formal research questions below, is defined to refer to aspects and features which fall outside the normative patterns of enactment that emerged within the set of case-study teachers. A formal statement of this research is as follows:

1) What was distinctive about the enactments of these two teachers that may have been important factors in their class’s post-unit test performance?
    a. What was distinctive about Marilyn’s enactment, compared to the other case-study teachers, which might have been important factors in her class’s poor performance?
    b. How did Gayle compare to Marilyn and the other case-study teachers in terms of the distinctive features established in (a)?
    c. What else was distinctive about Gayle’s enactment compared to the other case-study teachers, which might have been important factors in her class’s successful post-unit test performance?
2) Does there appear to be any relationship between these distinctive features of enactment and the teacher-training workshop attended?

As previously stated, categorization of classroom events in terms of the SimCalc principles appeared to fall within a wide spectrum with no clear patterns. Therefore, a deeper, or at least different, analysis was needed in order to uncover distinctive features of Marilyn's and Gayle's enactments. This was in fact accomplished by taking a broader rather than a more fine-tuned view. Certain observed features of Marilyn's enactment readily stood out as unique within the case-study sample: 1) she pushed through the material in a lesson-per-day style, regardless of whether or not the students finished the material in the lesson, and 2) she “walked” the students through a good deal of the material, working out the first page or two of each workbook lesson together as a class before allowing the students to work independently or in small groups. These observations provided a launching point for further analysis.

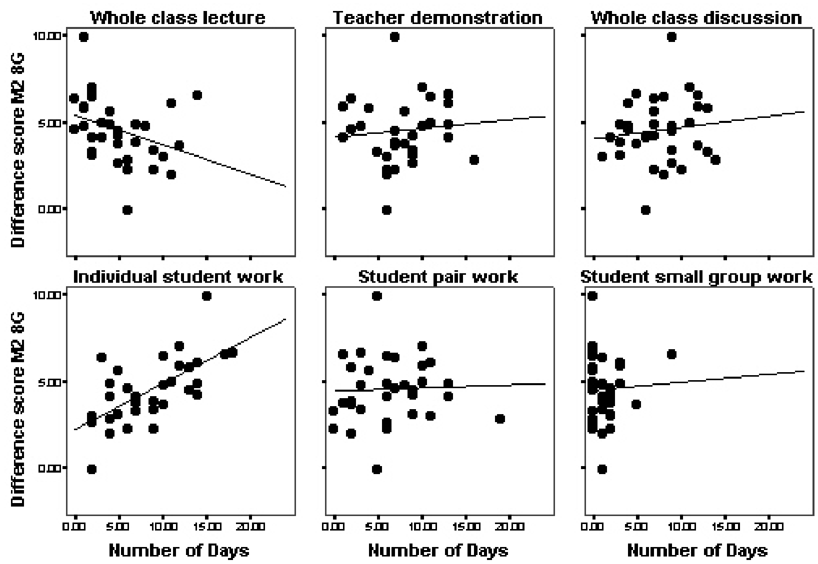
With this perspective, certain data from the overall project became especially relevant in attempting to isolate both what was distinctive and what was *not* distinctive about the two focus teachers. This data included teacher characteristics, student/classroom characteristics, and various statistics from the pre-unit and post-unit student test scores. In addition, information noted in the teacher's daily logs was used to supplement the three-day observation period for a more complete picture of the teacher's implementation of the intervention, and to substantiate certain inferences made from the observation data.

3.3.1.1 Episodes

Another issue that became increasingly relevant was the structure of the enacted lessons. Data from the larger project indicated that within the treatment group, there was a significant negative correlation between classroom mean gains on M2 (mathematics beyond typical 8^{th} grade material) and whole-class lecture activity, and a significant positive correlation between these same gains and time spent on individual student work. (see **Figure 4** below). This suggests the students learned more working independently than through a teacher's lecture, which in turn suggested potential benefit in coding lesson structure from these perspectives to gather more information on this possibility.

Activity Structure Findings
8G SimCalc Study

In the Treatment group, here is the relationship between the count of days spent doing at least some of each activity structure, and student M2 gains.



Correlations:

		Difference score student M2 8G (teacher-level)
Difference score student M2 8G (teacher-level)	Pearson Correlation	1
	Sig. (2-tailed)	
	N	33
Whole class lecture	Pearson Correlation	-.345*
	Sig. (2-tailed)	.049
	N	33
Teacher demonstration	Pearson Correlation	.105
	Sig. (2-tailed)	.560
	N	33
Whole class discussion	Pearson Correlation	.121
	Sig. (2-tailed)	.501
	N	33
Individual student work	Pearson Correlation	.643**
	Sig. (2-tailed)	.000
	N	33
Student pair work	Pearson Correlation	.042
	Sig. (2-tailed)	.817
	N	33
Student small group work	Pearson Correlation	.045
	Sig. (2-tailed)	.802
	N	33

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

Figure 4: Activity Structure Findings *(in preparation)*

The actual observation data, however, made it difficult to define individual work separately from pair/group work: every class had students either paired or grouped in some way, and the teachers often did not directly specify whether work should be done individually or within the pair/group. Thus, most often students were either explicitly or implicitly allowed to work together. Still, these correlations along with theories from the larger project suggested benefit in at least distinguishing between whole group work, where the teacher is always involved, versus smaller group work in which most students are functioning independently from the teacher. Coding was thus designed to capture these two categories, coded as “whole group” and “individual/small group” work.

The line between whole-class lecture and whole-class discussion was similarly fuzzy: although whole-class work was often teacher-centered, student participation was always encouraged in some way; very little observed activity was clearly lecture (teacher presenting information with students simply listening/taking notes). On the other hand, observations did suggest there were different types of whole group work serving different purposes and thus the coding process was designed to distinguish among these, as described below.

Recall that lesson structure was captured using a broad coding scheme in the TIMSS 1999 Video Study (Hiebert et al., 2003), which defined three purposes of different lesson segments in the typical classroom: *reviewing, introducing new content,* and *practicing new content.* Using this work as a guide, along with the aforementioned knowledge of the observation data and activity structure findings of Figure 4, analysis for this study divided lessons into segments called *episodes* of four possible types: ***reviewing, introducing, students working on problems,*** **and** ***follow-up***.

- ***Reviewing*** episodes are defined as in the TIMSS study, capturing each segment of time in which teachers addressed content introduced in previous lessons.
- ***Introducing*** episodes are defined as any segment of time when the teacher engages the entire class in discussing a problem in the workbook that students have not yet spent time on.
- In the TIMSS study, *practicing new content* included time spent not only on practicing and applying content introduced in the current lesson, but also any follow-up discussion of this material. For this study, this category was divided into ***students working on problems*** episodes and ***follow-up*** episodes. The category ***students working on problems*** is defined to include all individual and small group work, i.e., work time in which most students are functioning independently from the teacher. Any whole group work done *after* students have attempted the problem is considered a ***follow-up*** episode.

Once episodes were coded, the amount of time each teacher spent in each category was calculated and also reconfigured into percentages of that teacher's total teaching time.

3.3.2 Training data

Since the trainer interview questions were conducted similarly for each trainer, training interview data was coded first by question, but then also coded for a variety of aspects including the trainer's mathematical, pedagogical, and technological goals for the workshops, any intentions they had to adapt the materials, and how they planned to make their goals and intentions explicit to the teachers.

As for the training video data, once it was described in detail through the logging process, synopses of each lesson were written which included the main points about how each activity in the lesson was approached and discussed. The amount of time spent on each activity was calculated and recorded, separating the time spent in whole group discussion versus small group work. Also included were videotape library numbers and time stamps so that video of specific training activities could be rapidly found, speeding up access through the vast amount of data when necessary. This synopses data was stored in Excel spreadsheets, a format that provided a convenient means of comparison across regions for each lesson and activity.

After distinctive features of the two focus teachers were determined, analysis continued through the training session data with a focused intent, looking specifically for links between these particular features and the teachers' training experiences. In general, coding for the training observation data was limited to isolating possible connections to these features. The synopses data was used to determine where to look in the more detailed descriptions for relevant information.

Observation notes taken during the Region A planning workshop were used to locate points in the video data from that planning day that were also relevant to the distinctive features of Marilyn's enactment. The debriefing session between Marilyn and Trainer A, videotaped after Trainer A observed Marilyn teaching a lesson of the unit, was similarly used to provide additional insight into possible influences resulting in these distinguishing features.

Chapter 4: Case Study Teachers

Participant selection for this study was a product of both plan and situation. The research was limited to three regional workshops, as detailed in the methodology section, for practical reasons: of the two workshops not observed, one had only one confirmed participant and the other was conducted over a time period conflicting with two of the other workshops; furthermore the workshop facilitator did not wish to be videotaped (for personal reasons not related to the study). After observing the three chosen regional workshops, two to three teachers from each of these regions were selected to be case-study teachers. The original plan was to choose one experienced and one fairly new teacher from each region. While there was no attempt to choose the very best teachers, the selection process did look for teachers who were likely to be successful implementers. A short list of possible teachers to select was constructed based on input from the trainers, teacher responses to workshop end-of-day journal questions, and observations and impromptu talks with the teachers during the regional workshops. The journal questions were reviewed to identify teachers who expressed a clear articulation of their workshop experiences and reflected a positive attitude about the intervention. The trainer's input to this process was informal; the Region C trainer was the only one to specifically indicate teachers that she thought would be interesting to follow (as described below). The other two trainers simply discussed what they knew about their teachers during interviews and informal chats with the researcher. In regions A and C, final selections took place on Planning Day after talking to the teachers about their schedules.

In region A, out of the eight workshop attendees, Wendy and Kate stood out as being especially vocal and involved in the workshop. The trainer spoke well of these two teachers. Wendy appeared to be the strongest mathematically, based on the workshop observations and the fact that she had taught at the high school level, and was thus first choice for the study. Two fairly new teachers attended the workshop, but both dropped out of the study before teaching the unit due to circumstances beyond their control. Since this left the study with no "new teacher" for this region, Marilyn was chosen as an alternative. Marilyn was described by the trainer as a "traditionalist", which implied to this researcher that her teaching style was generally teacher-centered and lecture driven. However, the trainer also mentioned that Marilyn had attended a number of TEXTEAMS (Texas Teachers Empowered in Mathematics and Science) trainings, and was open to new ideas. This was in contrast to some of the other remaining teachers, who the trainer mentioned were sometimes negative about trying new things. Furthermore, timing was such that it was possible to schedule observations with both Marilyn and Kate on the same days, and so both were selected, along with Wendy, as case-study teachers.

Only four teachers attended the training in Region B. One of these dropped out before teaching the unit, because she had been re-assigned and would no longer be teaching 8th grade. Since this researcher was unable to attend the Region B Planning Day, the other three were all invited by email to participate in the study. Two, Sharon and Gayle (a 2nd year teacher), responded immediately and plans were made to travel and observe. The third teacher responded at a later date, having misplaced the email. Trainer B had spoken highly of this teacher, and she would have made an excellent choice for the study; as it turned out, her class had excellent post-unit gains. But she was teaching at the same time as Sharon and plans had already been made with Sharon. Visiting both teachers in one trip was not possible due to scheduling problems, and so the decision was made to stick with a full 3-day observation of Sharon.

In region C, the workshop trainer suggested a group of teachers from a particular district with a good reputation, and also a 2nd year teacher (Jackie) from a different district that took copious notes and was an active participant in the workshop, as possible case-study teachers. The implication to this researcher was that these recommended teachers would likely enact the materials in effective and perhaps interesting ways. Final selection was decided on Planning Day in September. At that point, this researcher had planned to choose a particular teacher from the recommended district, based on observing this teacher in the workshop and the teacher's well-articulated and positive journal entries. However, by Planning Day this teacher had already taught the unit (as it turned out, this teacher's class ended up doing quite well on the post-test.)

But Jackie and an alternate choice from the recommended district (Carly) were planning to teach their unit around the same time, and thus those two were chosen so that the observations could be accomplished in one trip to Texas. Samuel, another 2nd year teacher, was co-teaching with Jackie, so he was selected as well.

4.1 Description of Case-Study Teachers

4.1.1 Region A Teachers

4.1.1.1 Kate

Kate taught in the same medium-size city (pop 200,000) where the Educational Service Center for Region A is located in West Texas. Kate's school was a large brand new middle school. Her pre-unit log claimed the school supported a student body of 58% economically disadvantaged, although data from the larger project indicates a rate of 30.4% free lunch.

After attending the summer workshop, Kate was promoted to the position of math coordinator for her district. Having no current classroom of her own, she satisfied her responsibility to the project by co-teaching the unit with another teacher. During observations, Kate facilitated all whole-class discussions, but both Kate and her co-teacher assisted students during small group and individual work times.

The unit was taught in a computer lab to a target class of Algebra I students. Of the case-study classrooms, this was one of the largest (with 21 students), but also the only Algebra I class; all other case-study classes were at a lower level of study. Furthermore, the average pre-test score for Kate's classroom was well above average, in fact a full standard deviation above the average of all treatment classrooms and two standard deviations above the case-study sample in both M1 and M2 knowledge and skills. Kate and her co-teacher taught the unit to their 5th period Algebra I class as well "to keep them together."

At the time of the observations, Kate had 15 years experience and Master's degrees in both grades 1-8 science and middle school math. The Region A trainer spoke well of Kate and how she incorporated what she learned from professional development into her classroom practice in the past. Kate's mathematics background, however, included no calculus and she had a pre-MKT score in the 2nd quartile of the overall-study sample.   During the interviews, Kate noted that she had never taught the concept of *rate* before in a math classroom, having taught mostly 4th -7th grades. Kate appeared confident and articulate during the summer workshop, but in contrast seemed somewhat stressed and unprepared during the Planning Day in late August, apparently due to the responsibilities of her new position. During the observation days, she mentioned stress from the new curriculum job and said she felt she was not at her best in teaching this unit.

4.1.1.2 Marilyn

Marilyn taught 8th grade in a medium-size middle school in a larger town (pop. about 10,000) about an hour from the Region A Educational Service Center. In her pre-unit log, Marilyn described the school as a Title 1 school with a predominately Hispanic population (69.7% Hispanic, 24.7% white, 5.1% African American, .3% Native American, .3% Asian). Her log claimed a student body 65.7% economically disadvantaged, which agrees with the % free lunch reported by the larger project

Marilyn used laptops in the classroom rather than take the class to a computer lab. Her target classroom consisted of a mix of students including both high and low achieving students, English language learners, and mainstreamed special education students. The average pre-test score for Marilyn's class was slightly below average among the case-study classrooms.

Marilyn was a veteran teacher, with eight years experience teaching 8th grade mathematics, plus a few more years experience teaching younger grades. She had a B.S. in education, with a basic math background in algebra and geometry (no calculus). Her pre-MKT score was in the 2nd quartile.

Marilyn was somewhat quiet during the summer workshop, but was always friendly and seemed positive about the intervention during casual talk with this researcher, and was also welcoming and cooperative to this researcher when selected as a case-study teacher. During her case-study interviews, she expressed gratitude to her principal for giving her release time to review and prepare before teaching the unit. She frequently spoke well of the principal's support for the project.

4.1.1.3 Wendy

Wendy taught in a small rural town (pop under 2000) about an hour and a half from the Region A Educational Service Center (ESC) (in a different direction from Marilyn's school). Wendy describes the school and community in her pre-unit log:

> Our community is small and very supportive of our school. The community is an agriculture community with many migrant students in and out of our school system. The junior high is grades 5-8 and I teach all mainstreamed 7th & 8th grade math students. We are a high performing campus--we were rated exemplary by TEA for the 2005-2006 school year. We are an inclusion school.

Wendy's target class consisted of seventeen low-achieving students, which included both English Language Learners and seven mainstreamed special education students. The average pre-unit score for Wendy's class was the lowest among the case-study teachers, more than a standard deviation below the case-study average. Wendy expressed the belief that these students could learn the material, but would need more time (personal communication, 10/23/06). Like Marilyn, Wendy used a class set of laptops in the classroom when teaching the unit.

Wendy was also a veteran teacher, with 13 years of experience including time teaching at the high school level. Wendy's B.S. degree in Mathematics gave her the strongest mathematical background of any of the Region A teachers. Her pre-MKT score was in the 3rd quartile, not towards the top overall but surpassing her Region A colleagues.

Wendy was very vocal in the workshop, and answered many of the questions posed by the trainer during whole group discussions. Having tested out the unit on her Algebra I class early in the academic year, she came to Planning Day confident and positive, providing guidance and suggestions to the group. She shared stories about setup issues, and described how impressed she was that the Algebra I students were able to figure out so much of the unit on their own. She encouraged the other teachers to allow time in the beginning of the unit to let the students "play" with the software, and to guide the students rather than to explicitly teach. She described how one group of boys in the Algebra I class had pushed their desks together, and "came up with all the interesting stuff".

4.1.2 Region B Teachers

4.1.2.1 Gayle

Gayle taught in the small city (pop around 100,000) where the Region B Education Service Center is located in northern Texas. Gayle described her school as a "low economic body" Title I school with a high number of students (over 50%) on free or reduced meals. Data from the larger project indicates 44% of students on free lunch.

In Gayle's school, individual teachers did not teach autonomously, but rather followed the instruction plans of a lead teacher. To accommodate the SimCalc unit, this lead teacher decided that all five 8^{th} grade math classes at the school would use the unit. Gayle herself taught the unit to two separate classes.

Gayle taught the unit in a computer lab. Her target class of nine average-achieving students was the smallest of the case-study teachers. Interestingly, although the class average pre-test score was close to the both the case-study sample and treatment sample averages overall, the corresponding M1 score was quite a bit below average (about half a standard deviation), while the M2 quite a bit above average (almost ¾ of a standard deviation in the case-study sample).

Gayle was a 2nd year teacher, with a bachelor's degree focusing on grades 4-8 mathematics, and no calculus in her math background. Her pre-MKT score was in the first (lowest) quartile. Gayle was very quiet during her workshop experience, always attentive but making few comments.

4.1.2.2 Sharon

Sharon taught in a Pre-Kindergarten through 12th grade school in a small rural town (pop under 2000). The entire school housed 185 students. There was one class per grade, and no special education room – all students were mainstreamed. Sharon stated that a very high percentage of her students were of low socioeconomic class (45% of students eligible for free lunch).

Sharon taught the SimCalc unit to her fifteen 8th grade students in the computer lab. As there was only one class per grade, this class contained all ability levels, including both gifted students and special education students. Sharon mentioned during the workshop that five of her 17 students are special education students, who were mainstreamed just the year before. (Note only 15 students total participated in the study). The class average pre-test score was somewhat below but fairly close to average for both the case-study and treatment samples.

Sharon had a degree in mathematics and was the sole math teacher in the school for grades 7 through 12, including calculus. She had 6 years experience at the time of data collection. Her pre-MKT score was in the 3rd quartile. Sharon was quite vocal during her workshop experience, frequently making comments and asking questions.

4.1.3 Region C Teachers

4.1.3.1 Jackie and Samuel

Jackie and Samuel team-taught the SimCalc unit in a middle school in a major city of Texas (population about 700,000). The teachers described the school as a Title 1 school. Although not located in the center city, the school's free-lunch percentage (91.7%) is a clear indication that the school consists of predominately low SES students.

Samuel described his class as average achieving, which corresponded with a class average pre-test score very close to the treatment average (M1 and M2 scores close to average as well). Jackie's class was somewhat more difficult to categorize. While describing her class as a high achieving "pre-AP" class (students on-course to eventually take AP math classes in high school), the average pre-test scores did not seem to correspond, with an overall average raw score almost a full 2 points below Samuel's average achieving class (9.6 vs. 11.5). Jackie mentioned English Language learners and one special education student, which may explain three very low scores, but only two of her twelve students scored above Samuel's class average.

While Jackie was the teacher originally chosen for this case-study, both teachers were observed and interviewed since they had decided to combine their classes to teach the unit. This decision to team-teach was made because their assigned target classes fell across the same period and there was only one computer lab in the school. Studying both teachers was actually advantageous, as the participating teachers in the observed regions were predominantly white females and Samuel's inclusion gave the study a case participant who was both male and African-American.

Jackie and Samuel were interestingly similar in some ways. Both were second year teachers with strong math backgrounds. Jackie had a degree in Physics, while Samuel was a former engineer. Both scored in the 4^{th} quartile on the pre-MKT test. Both Jackie and Samuel were active and attentive during the workshop, occasionally sharing during whole group discussion. Jackie made more comments and took copious notes during the workshop, thus catching the eye of the trainer, who recommended her as a case-study participant.

Jackie and Samuel are included in this study in as many ways as possible. Unfortunately, observation data is limited for their class. Three days of observation were planned, as with the other classrooms, but only a day and half was actually collected, due unexpected and uncontrollable circumstances.

4.1.3.2 Carly

Carly taught at a middle school in a rather large suburban town (pop about 8000) about a half-hour drive from the major city where Jackie and Samuel taught. Carly's school had much higher SES students (39.1% free lunch) than Jackie and Samuel, but was comparable to some of the other case-study schools.

Carly's target class of 22 students was the largest in the case-study sample, other than the total of Jackie and Samuel's combined class. Carly described her target class as average achieving, with inclusion special education students. However, the class average pre-test score was low for the treatment sample (.6 of a standard deviation below average) and also for the case-study sample; only Wendy's class scored lower on the pre-test (Jackie's average M2 score was slightly lower as well).

Carly was a veteran teacher with 8 years experience, all in 8^{th} grade mathematics. Her mathematics background included calculus (through multi-variable), and her pre-unit log indicated that she took many pedagogy classes (more than any other case-study teacher). Her pre-MKT score was in the 4^{th} quartile. Carly was attentive and active during the Region C workshop, but did not especially stand out in the overall group of fourteen participants, other than her journal entries which demonstrated thought and insight.

Carly's class had two separate 40-minute math sessions per day. Three sessions were observed, the first session of the first day and then both sessions the second day. A third day of observation had been scheduled, but was cancelled due to a school emergency.

4.2 Similarities among the Case Study Teachers

Observations provide ample evidence that neither the training workshops nor the classroom enactments were scripted experiences; variety was definitely the norm. But there were common threads, i.e., certain major aspects of the intervention reached every observed classroom. In particular, there was one overarching main idea of the materials that seemed to resonate among the teachers: the concept that in a linear or piece-wise linear graph, the steepness of the line provides information about the speed of the motion it represents. This idea appeared to carry well throughout the unit, playing a role in every observed classroom regardless of which lesson was being taught. The following examples include all teachers except Jackie and Samuel:

Kate is observed addressing this big idea in Lesson 2. Although she does not use the word “steep” and doesn’t take advantage of the projected image of the software at her disposal, she gets across the big idea using gesture:

> **Kate**: What happens to the slope of the line, does it go down or up if you want to speed it up? [Kate is gesturing a line with her arm]
> **Students:** Up
> **Kate:** Up? OK. What if I want to slow it down, is it going to go up or down?
> **Students**: Down
> [Kate gestures downward with her arm, representing a line with a less-steep slope].
> **Kate**: Down. OK.

This same big idea is discussed in Wendy’s class during Lesson 4. In this excerpt, Wendy has just run a Lesson 4 simulation on her SmartBoard:

> **Student**: One of the little dudes is going slow, and one’s fast.
> **Wendy**: OK. One’s going slow, one’s going medium, one’s going fast. How can you see that on the graph?
> [Several different students call out various ideas all at once]
> **Wendy**: Are they going different directions? Or, what’d you say <student name>?
> **Student:** The line, the one that’s going faster, the line is steeper.
> **Wendy**: Very good. The guy who’s going faster, his line is steeper.

Gayle is first observed addressing the big idea in Lesson 5, as the class is discussing the first activity of the lesson:

> **Gayle**: .. slowly, is that important?
> **Student**: Yes, the line won’t be as steep.
> **Gayle**: The line will not be as steep. She’s moving slowly when she’s in the swamp. So when she’s in the swamp she’s slow, forward faster when she’s on the road. What kind of line are we going to see with forward faster?
> [Student answers quietly]
> **Gayle:** Say it.
> [Student answers quietly]
> **Gayle**: Steeper.

Marilyn was observed discussing this big idea in a review of Lesson 5:

<u>Lesson 5</u>
Marilyn: Then what happened when Wendella started moving again, only she was in the swamp?
Student: She's moving slower.
Marilyn: Moving slower. How do we know that from the graph?
Student: Because it wasn't as steep.
Marilyn: Was not as steep, and then when she got to the road, what happened to the line?
[Student answers quietly]
Marilyn: Went steeper, right?

In Carly's class, the big idea comes up in Lesson 6, and Carly connects this situation (involving money) with the experiences from previous lessons, which involved character motion. This excerpt begins with a graph of the monthly balances of a bank account, with a student explaining his answer to the question "month with the highest increase in balance":

<u>Lesson 6 (Money Matters):</u>
Student [at projector screen, pointing to a graph]: From here to here is 10,000 and from there to there is 10,000, but this is from zero to 20,000.
Carly: OK. How did he know, let's say there were no numbers on the graph, maybe we lost our numbers for some reason, how could he still know that's the biggest increase?
[different students calling out answers]
Student: Look at the gap. [gesturing with her arms]
Carly: OK. What's special about that gap than the other ones?
Student: It's longer and it's more steeper [gesturing with her arms]
Carly: It's steeper right? There's that whole steepness thing again. Steepness with our characters meant they were moving …
Students: faster
Carly: Faster. Steepness with our money means what?
Student: They're gaining money.
Carly: They're gaining money … what's an adjective?
Student: Faster.
Carly: Faster. They're gaining money faster. So that was a bigger increase.

Sharon is observed addressing the big idea in Lesson 8:

Sharon: It says that Red Riding Hood moves at 2 different velocities. How do I know she has 2 different velocities by looking at the graph? All of you have it open.
Student: The line – one line is steeper than the other

> **Sharon**: One line is steeper than the other, <student name> said. Is she right?
> **Students** [chorus]: Yes.
> **Sharon**: If you look at Red Riding Hood's line, part of it is steeper, that is correct. Is she going faster when it's steeper, or slower?
> **Students** [chorus]: Faster.
> **Sharon**: Faster. The steeper that the line is, the faster she's going.

There were other basic similarities among the enactments. All observed classrooms spent most if not all of class time focused on the provided curriculum materials; i.e. it appears that add-on activities were fairly minimal. No add-on activities were observed in any of the case-study classrooms, but teacher daily logs do indicate that some occurred; in most cases taking up a full class period rather than combining these activities with the SimCalc unit activities (see ***Table* 1** below).

Table 1: Classroom Activities Outside of Unit Curriculum

Region	A			B		C	
	Kate	Marilyn	Wendy	Gayle	Sharon	Jackie & Samuel	Carly
CBR (1 full period)	X	X					
Map of Texas (for Lesson 2, to show where cars were traveling) *		X					
Teacher-created review sheet for unit material **		X					
Textbook *						X	
Project "Whale's Tale" *							X
Homework on Finite differences *							X
Worksheet "Measuring Up" (1 full period)			X				
Worksheet: "Coordinate Plane" (1 full period)			X				

* Workbook activities also completed on same day; unclear how much time these activities took
** Handed out towards end of period

Gayle and Sharon (both from Region B) did not indicate any add-on's. Kate and Marilyn (both from Region A) each devoted a day to CBRs (Calculator-Based Rangers) as part of their enactment of Lesson 5 (which introduces piece-wise linear motion). Marilyn's other add-on's were connected to the unit activities. Jackie and Samuel indicated they used their textbook on two occasions, but failed to specify what pages of the textbook, so it is unclear how or if this work connected to the unit. Wendy, with a target class of low-achieving students, took two consecutive days to work on worksheets (for a full class period each) mid-way through the unit (after Lesson 5). Carly indicated the most add-on work, indicating students worked on a special project and homework on finite differences, both for 2-3 days each. From the log, it is unclear whether these activities were assigned as homework or took up class time (her class completed several pages of the SimCalc workbook as well on the days these activities are noted).

The teacher's guide provided a short list of "Big Ideas" for each lesson, i.e., main concepts to emphasize; another similarity is that these "Big Ideas" were in fact emphasized, to varying degrees, in all the observed classrooms. For instance, all four classrooms observed teaching Lesson 5 emphasized that a graph can tell a story. In two classes (Kate's and Gayle's), the story was the emphasis, with many stories (that described graphs) shared with the entire group. In another class (Marilyn's), the stories were written but not shared, and the teacher repeated "that graph tells a story" or "it's a story about a graph" several times. In the other class (Carly's), the graph was the emphasis: stories were shared with a partner, and whole class time was spent on understanding the story's graph (as it related to its corresponding motion) in more detail.

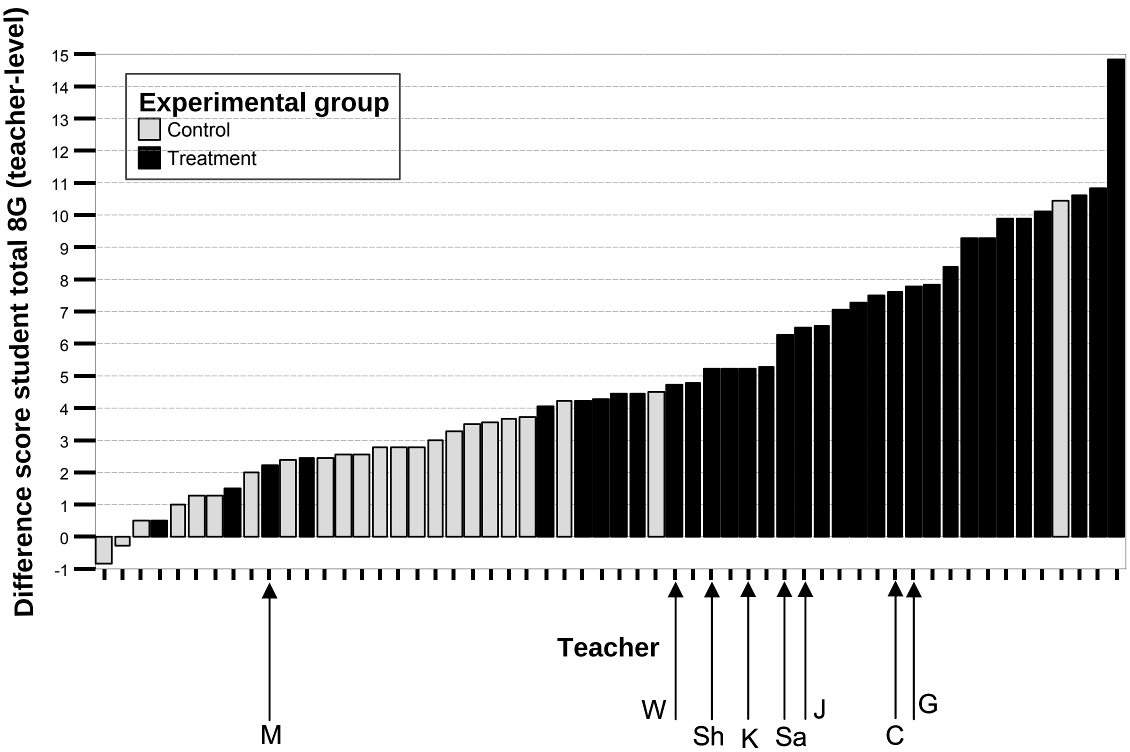
Another similarity among the case-study classrooms is that students were given substantial access to the SimCalc software. Each class included time devoted to small group or individual work, where students were free to use the software as they wished. In almost all cases, students had access to an individual computer, although certain teachers requested students work in pairs or groups on one computer for certain activities.

There were, however, differences in how teachers focused the students on the software. For instance, an activity in Lesson 4 had students choose a start position and speed for a character, write the equation and sketch the corresponding graph, and then use the software to check their work. One teacher (Gayle) was observed checking student work, and helping them by-hand if incorrect, before allowing them to test with the software, which in general was done without teacher supervision. In contrast, another teacher teaching the same activity (Wendy) was observed using the software to help an individual student choose and understand a reasonable domain for the motion of the character, asking the student to change the SimCalc graph to reflect his chosen starting point, and pointing out to the student that changing his SimCalc graph to agree with his sketched graph changed the corresponding SimCalc equation, which then no longer agreed with his equation.

These differences in approach and focus may have affected student's interactions with the software, but does not circumvent the fact that students had time to use the software as they wished; they were not restricted to following teacher directives. There may have been students in either class that used the software more productively, or less productively, than the videotaped interactions described above. Since the video camera for this sub-study followed the teacher, data on student interactions with the software is limited, but students were observed running the simulations and manipulating the graphs in all classrooms, often at times and in ways not specifically specified by the teacher.

4.3 Special Focus: Marilyn and Gayle

The following figure (**Figure 5**, a copy of **Figure 3**) indicates where the case-study teachers fall within the overall results of the SimCalc study, in terms of teacher-level student gains.



Arrows denote teachers in this study, table denotes teachers and workshop region

Teacher	**Workshop Region**
M: Marilyn	Region A
W: Wendy	Region A
Sh: Sharon	Region B
K: Kate	Region A
Sa: Samuel	Region C *(combined class with Jackie)*
J: Jackie	Region C
C: Carly	Region C
G: Gayle	Region B

Figure 5: Mean gains by classroom

Marilyn and Gayle have been chosen to describe in more detail, because of their knowledge and teaching styles versus the performance of their students in this study. There was reason to suspect that the students in both classes might perform poorly on the post-test. Marilyn "walked" her students through a great deal of the material. Although the software was projected on a side wall, the main focus in the classroom was the current workbook page projected via an overhead projector. A good deal of the class time seemed to be spent discussing and writing down the answers on this overhead; a confused or disinterested student could simply copy everything down. When Marilyn helped students individually, she often took over the mouse and worked with the software herself, explaining to the student as she worked. Gayle, on the other hand, gave her students more autonomy but appeared to focus them on procedural issues. The formula "d=rt" was emphasized, and the software used sparingly in ways that seemed limiting. Gayle didn't use a projector to display either the software or the workbook pages; there was no common visual at all. Despite SimCalc's motion and graphical capabilities, Gayle often focused the class on algebraic reasoning as if there was no alternative.

Although this information was not available at the time of the observations, the MKT scores of these two teachers provided more reason to suspect the possibility of low performance in these classrooms: as Table **2** below indicates, Gayle had the lowest pre-unit MKT score of the entire sub-study sample, the only one in the lowest quartile, and Marilyn's MKT score in the 2nd quartile was tied with Kate as the second-lowest score.

Table 2: MKT Scores of case-study teachers

	Region	MKT Quartile Pre-test
Kate	A	2
Marilyn	A	2
Wendy	A	3
Gayle	B	1
Sharon	B	3
Jackie	C	4
Samuel	C	4
Carly	C	4

However, student performance in Marilyn's and Gayle's classes turned out to be on opposite sides of the sub-study sample spectrum. At the teacher level, student gains in Gayle's class were higher than all other case study teachers. On the other hand, as Figure 5 above illustrates, student gains in Marilyn's class were not only 3rd lowest of all the treatment classrooms, but also lower than many control classrooms. In fact, Marilyn's class had an average gain lower than 70% of the control group classrooms. This is quite a contrast from the majority of treatment classes (and all the other case-study teachers), who outperformed all but one of the control classrooms in terms of student gains.

As we shall see, Marilyn and Gayle, along with their classes, do not especially stand out in terms of general aspects such as SES, student ability, etc. Thus, studying these two teachers has the potential to shed light on several important issues. Both teachers started out reportedly weak in Mathematical Knowledge for Teaching, and taught in a manner that did not seem to capitalize on the power of the intervention, and yet one was much more successful than the other. What are the possible factors that may have led to this? Did their training experiences play a role?

Predicting which teachers will be most successful does not appear to be easy; Gayle is not the only example of a teacher who surpassed researcher expectations. As mentioned in my description of teacher selection, there was a teacher in Region B and also one in Region C that I had wanted to observe but could not. This was disappointing because, as it turned out, both these teachers had high average gain scores and may have provided insight into an exemplary enactment. However, while I was checking their scores, I checked a few others as well. Two other teachers, one in Region A and one in Region C, that I did not consider as possible case study teachers because they seemed somewhat weak compared to other potential choices (e.g. less experienced, less confident, very distracted during the workshop), *also* had high average gain scores. Furthermore, the 7th grade portion of the SimCalc study had cases of teachers who appeared to enact the materials less skillfully but had quite successful results (see for example "Teacher G" in Empson, Greenstein, Maldonado, & Chao, 2008). Thus there is ample reason to try to understand possible underlying factors in such cases.

Overview information

The following tables give overview information concerning the case-study teachers and their classrooms. These tables (or portions of them) have been or will be repeated separately as needed, but are provided here as a reference for a more holistic view.

Table 3: Teacher experience (self-reported)

	Kate	Marilyn	Wendy	Gayle	Sharon	Jackie	Samuel	Carly
Professional Practice								
Grade 5								
Years Teaching math	3		1		0			
years teaching total	3	4	13		0			
Grade 6								
Years teaching math	8		0		2			
years teaching total	8	4	13		2			
Grade 7								
Years teaching math	3	2	3	1	6			
years teaching total	3	2	13	1	6			
Grade 8								
Years teaching math	1	8	12	1	6	1	1	8
years teaching total	1	8	13	1	6	1	1	8
Grade 9								
Years teaching math			8		6			
years teaching total			13		6			

Table 4: MKT Scores of case-study teachers

	Region	MKT Quartile Pre-test
Kate	A	2
Marilyn	A	2
Wendy	A	3
Gayle	B	1
Sharon	B	3
Jackie	C	4
Samuel	C	4
Carly	C	4

Table 5: Description of case study classrooms

Teacher	**Class size**	**Class description (taken from teacher log)**	**Title 1 school?**	**% free lunch**
Kate	21	High achieving	?	30.4%
Marilyn	12 [15 in observation video]	Average achieving, High achieving, Low achieving, LEP/ESL learners, Special ed, 2 students who are mainstreamed	yes	65.7%
Wendy	17	Low achieving, LEP/ESL learners, 7 special ed, all mainstreamed with modifications	?	68.8%
Gayle	9	Average achieving	yes	44.0%
Sharon	15	only 8th class in school, all ability ranges in this classroom, including three spec. ed students and two borderline spec ed students	?	43.9%
Jackie	12	High achieving, LEP/ESL learner, Pre-AP, TAG, Special ed (just one)	yes	91.7%
Samuel	13	Average achieving	yes	91.7%
Carly	22	Average achieving, special ed (inclusion)	?	39.1%

Table 6: Teacher-level Pre- and Post- test results

Teacher	Avg pretest score	Avg posttest score	Avg M1 pretest	Avg M1 posttest	Avg M2 pretest	Avg M2 posttest	Avg gain	Avg M1 gain	Avg M2 gain
Kate	20.8	26.0	11.3	12.4	9.5	13.7	5.2	1.1	4.1
Marilyn	9.5	11.8	6.2	6.1	3.3	5.7	2.3	-0.1	2.3
Wendy	5.4	10.1	3.6	5.5	1.8	4.6	4.7	1.9	2.8
Gayle	11.3	19.1	5.1	9.2	6.2	9.9	7.8	4.1	3.7
Sharon	10.3	15.5	6.1	7.1	4.2	8.5	5.2	0.9	4.3
Jackie	9.6	16.1	6.8	8.4	2.8	7.7	6.5	1.6	4.9
Samuel	11.5	17.8	7.2	9.3	4.4	8.5	6.3	2.2	4.2
Carly	7.5	15.0	4.4	7.0	3.0	8.1	7.6	2.5	5.0
treatment average	11.2	17.7	6.9	8.9	4.3	8.8	6.5	2.0	4.5
treatment stdev	4.6	6.3	2.2	3.0	2.5	3.4	3.1	1.4	1.9
control average	11.4	14.2	6.6	8.2	4.8	6.0	2.7	1.6	1.2
control stdev	5.3	5.4	2.6	2.5	2.8	3.0	2.2	1.2	1.5

Table 7: Small treatment classes of predominantly average-achieving students

Teacher	MKT quartile	% free lunch	total students	# Low	# Med	# Hi	Class average pre-test score	Class average post-test score	Class average gain
Gayle	1st	44	9	0	8	1	11.3	19.11	7.78
T1	4th	13	9	1	6	2	11.9	17.11	5.22
T2	1st	57	11	2	6	3	9.6	14.91	5.27

Chapter 5: Marilyn

5.1 Comparison of Class Characteristics

Marilyn's classroom is notable because of the low gains her students achieved. ***Table* 8** can be used to compare the characteristics of her specific situation with that of the other teachers in the sample.

Table 8: Description of case study classrooms

Teacher	**Class size**	**Class description (taken from teacher log)**	**Title 1 school?**	**% free lunch**
Kate	21	High achieving	?	30.4%
Marilyn	12 (?) [14 in observation video]	Average achieving, High achieving, Low achieving, LEP/ESL learners, Special ed, 2 students who are mainstreamed	yes	65.7%
Wendy	17	Low achieving, LEP/ESL learners, 7 special ed, all mainstreamed with modifications	?	68.8%
Gayle	9	Average achieving	yes	44.0%
Sharon	15	only 8th class in school, all ability ranges in this classroom, including three spec. ed students and two borderline spec ed students	?	43.9%
Jackie	12	High achieving, LEP/ESL learner, Pre-AP, TAG, Special ed (just one)	yes	91.7%
Samuel	13	Average achieving	yes	91.7%
Carly	22	Average achieving, special ed (inclusion)	?	39.1%

Although only 12 students took both the pre- and post- test, observational data indicate there were at least 14 students in Marilyn's class. This number is still lower than all but one observed classroom (Gayle's), since Jackie and Samuel combined their classes for a total of 26 students taught simultaneously. In any case, the number of students in Marilyn's class was not substantially more or less than the other classes.

Looking at SES based on % free lunch, Marilyn's free lunch percentage is comparable to Wendy's, and much lower than Jackie and Samuel's. Although Gayle's % free lunch was lower (44% vs. 66%), Gayle's school was a Title 1 school which would still indicate an SES concern there as well.

Marilyn had a mix of students in her class, ranging from high achieving to LEP/ESL learners and two mainstreamed special education students. But Sharon had a similar mix, including three special education and two borderline special ed, while Wendy had a class of entirely low-achieving students including LEP/ESL learners and seven mainstreamed special ed. All but two teachers documented that they had at least one student with special needs.

As shown in ***Table* 9**, the average pre-test score for Marilyn's class was 9.5, not significantly lower or higher than the other case-study classrooms. Her classroom M1 average pre-test score was almost exactly the case-study average, and three of the seven other case-study classes had lower average M2 pre-test scores than Marilyn's class.

Table 9: Teacher-level pre-test results for case-study sample

Teacher	Class average pre-test score	Pre-test M1 (teacher level)	Pre-test M2 (teacher level)
Kate	20.8	11.3	9.5
Marilyn	9.5	6.2	3.3
Wendy	5.4	3.6	1.8
Gayle	11.3	5.1	6.2
Sharon	10.3	6.1	4.2
Jackie	9.6	6.8	2.8
Samuel	11.5	7.2	4.4
Carly	7.5	4.4	3.0
case study average	10.7	6.3	4.4
Treatment average (teacher level)	11.2	6.9	4.3

Thus, Marilyn's class does not stand out in this sample in terms of class size, SES, student ability or student prior knowledge. And yet this class does stand out, both with respect to the case-study sample and the overall treatment sample, in terms of low student outcome from the intervention.

What was different about Marilyn's classroom that might shed light on the class's lower performance? It would seem that the performance differences between Marilyn's class and the other case study classes was not likely due to class characteristics but rather in how the unit was enacted. Classroom observations suggest that Marilyn's classroom enactment is similar in many ways to most of the other case-study teachers, but it does stand out in certain ways. For example, she did not allow much time overall for the unit and organized the class differently than most other teachers, affecting student exposure to the materials in a manner not observed in the other classrooms.

The following three sections illustrate these issues and how they compare to the other case-study teachers. The first section discusses time spent and material coverage in Marilyn's classroom. The second describes Marilyn's enactment within the context of a particular lesson, with analysis to point out her organizational decisions and her level of directive teaching, both of which affected student's exposure and opportunities for autonomy with the materials. The third compares Marilyn's enactment of the unit with the other case-study teachers.

5.2 Time and Material

During each day of observation, Marilyn began her class on a new lesson in the unit. Class ended the first day with most students working on (not completing) the 3rd page (out of 5) of Lesson 5. Lesson 6 was skipped completely. Class ended on day 2 of observations with most students working on the 3rd page (out of 5) of Lesson 7. On the third day, some students finished the 2nd page (out of 2) of Lesson 8, and some did not.

During an interview, Marilyn explained that she spent two days on the first lesson, but discovered the material leftover from the first day did not require a full extra day. Concerned about time, by the third lesson she decided to let students continue to work during "TAKS class" rather than extend a lesson or activity into the next school day.

> **Marilyn**: There was one lesson where I took two days. You know that type of thing. And then after I did that, I realized I thought, this could take me a long time and so then that's when I went, you know I kind of and I think my lesson plans, I think I, I'm following my lesson plans pretty well. But on that day I did split up the lesson. But I really didn't, didn't need to. After I got into it, thinking because the very end of it, that next day, the second day wasn't a lot, we finished up early is what I'm trying to say …OK, *Controlling Characters with Equations* [beginning of Lesson 3]. This is where I started letting them finish up in TAKS class …

"TAKS class" is a shortened period, less than 25 minutes long, which occurred right after the treatment class period. The TAKS class is for students who failed, or who came close to failing, the 7th grade standardized TAKS (Texas Assessment of Knowledge and Skills) test. This particular TAKS class was essentially the same group of students as Marilyn's treatment class minus one special education student and five students who, due to their 7th grade TAKS score, were not required to attend.

During another interview exchange, Marilyn talks again about continuing the unit during TAKS class:

> **Marilyn**: The principal is letting me catch up during TAKS, and the five kids that leave, they just won't be responsible for the last few things that I've been teaching in class. And I can catch them up later. They're my higher level, it won't be a problem at all.

Marilyn arranged for another teacher to monitor the TAKS class during the first and third day of observation while she participated in the interview process for this study. On the second day (Lesson 7), observation continued through the TAKS class. Even with this extra time, the TAKS class students did not work on the final page of the lesson.

Marilyn skipped a good deal of material overall. Her daily log records that her class skipped the last pages of Lessons 4, 5, and 7, and completely skipped Lessons 6, 9, and 10. A brief workbook analysis indicates that some students skipped even more. Although Marilyn's log and interview reported the class completing Lesson 2, student workbooks reveal that four of her students did not attempt the final two pages (out of four) of the lesson. [However, this observation is incomplete; this study does not include a detailed workbook analysis. It is possible these students were simply absent that day.]

Marilyn spent three days less on the unit than her lesson plans had allotted. One day was due to a special school-wide competition. It is unclear why another day was skipped. On the last day Marilyn planned to spend teaching the unit, a heater in her room caught on fire and she had to take her students to the library, where she decided to forgo another day of instruction and simply administer the post-test.

Marilyn also noted in her daily log that one instructional day was on a shortened class schedule (second day of Lesson 1), and that discipline problems took up some time on two other days (during Lessons 2 and 3). During her first interview, conducted before starting Lesson 5, she acknowledges time as an issue, but still seems to be satisfied with her implementation of the intervention. The time constraints are mentioned as if they are beyond her control:

> **Q**: So how do you think the unit's going so far?
>
> **Marilyn**: So far really well. I mean you know I mean I've, as much as I can get into the class period. Like I said, yesterday, time's an issue. With the 45 minutes, it's a lot of time getting started and then closing, closing. So that limits my time to teach. And that type of thing. Other than that, I feel like they're getting something from it. I mean you know things are coming together. Now they're a little more used to the program and they know where to go. I mean they can manipulate the graph a little better. And so it is going a little better. I'm anxious to see how it's going to be when we get into the averages. That comes into the Red Riding Hood and that type of thing and seeing how far we can take it, so. We'll see. So far so good.

In a subsequent interview (conducted just before teaching Lesson 8), Marilyn again talks about time. One might discern a conflict in Marilyn's statement, as she notes a need to take sufficient time, but not too much:

> **Q**: What kind of advice would you give a colleague?
>
> **Marilyn**: What kind of advice? I don't know. Take your time. I mean that type of thing. There's probably, I would probably sit down with them and

> kind of go over some of the main points. So that we wouldn't spend an enormous amount of time because we have so much that we have to teach.

5.3 Class Organization and Level of Directive Teaching

Based on three days of observation, Marilyn often started class by reviewing previous material while laptops were warming up. She then went carefully over the early activities of the day's lesson with the entire class, for the most part going over the mathematics of the exercise before giving students the opportunity to try the activities on their own. The students then worked independently until the end of class on the rest of the material.

Activities were always done in the sequential order indicated in the workbook. No lesson was completed during any one period over the course of the three days of observation and there was never a carry-over to the next day, i.e. each day started a new lesson.

Marilyn sometimes reviewed big ideas of the previous day at the beginning of class, and referenced big ideas during class time. In general, students readily participated in class discussions, calling out answers to questions posed by the teacher. A specific student was seldom called upon to respond, so it is unclear what percentage of students actually participated in class discussions. Discussion involving justification was infrequent and brief, with student responses hard to hear, and the teacher re-voicing these explanations in an imprecise manner. Gesture was often used during explanations rather than explicit reference to a commonly-viewed graph, although such a graph was often available.

In general, the software was not a central focus of the activities and, when used, was most often employed as an observation tool rather than an exploration tool. When working with an individual student, Marilyn tended to manipulate the software herself, although with longer interactions she would pass control to a student. For whole class discussions, the software was displayed through a projector controlled by a student, but students most often focused on their laptops rather than the common visual. Marilyn herself stood near an overhead projector displaying a slide of the current workbook page, which she updated with answers as the discussion progressed.

Since both Marilyn and Gayle were observed teaching Lesson 5, this lesson will be described in detail in order to give further insight into issues of classroom organization and levels of directive teaching. The associated analysis includes references to other observation data as well.

5.3.1 Marilyn's Enactment of Lesson 5

Lesson 5, entitled *Wendella's Journey: Moving at Different Speeds* (see Appendix B), introduces students to multi-segment graphs that represent characters' movements at different speeds. In previous lessons, students had been exposed to simulations and corresponding graphical representations of constant rate forward motion, with separate simulation characters moving at different speeds and starting at different locations. In this lesson, the character Wendella the dog travels at various speeds in a single journey, represented by a piecewise linear graph.

The teacher's guide lists the following as the "Big Ideas" of the lesson:

- Multi-segment graphs can represent characters moving at different speeds.

- Graphs tell a story. Stories can be represented in the form of graphs. In this activity, students will learn to write stories from graphs and make graphs for stories
- “Flat” lines represent standing still.
- Lines “slanting downward” represent moving backward.

In the first simulation (with corresponding graph), Wendella moves forward quickly, then moves at a slower pace, then stops, then moves forward quickly again. Workbook instructions tell students *not* to run the simulation, but to look at the graph of this journey, predict Wendella’s motion from the graph, and write a corresponding story, in which Wendella is on a road moving fast, or a swamp moving slowly, or stopped by quicksand.

In Marilyn's lesson plan, she had allocated one day for Lesson 5. She had written as her plan:

> Wendella's Journey
>
> Have students make a prediction about Wendella's Travel.
> Then work through pages 24-28 in pairs.

The following description of the day’s lesson is broken into episodes reflecting class time organization (episode types are defined in Chapter 3).

5.3.1.1 Review episode

As the laptops are powering up in the classroom, the class discussed their experiences from the previous day. Marilyn had been absent, and had instructed a substitute to let the students explore motion and graphs with CBRs (Calculator-Based

Rangers). In this interlude, the class is discussing graphs with both forward and backwards motion: [T refers to teacher, S Student, Ss more than 1 student].

> **T**: Before we start, Lila was telling me that Friday was pretty different? Did you all like that motion detector?
> **Ss**: Yeah
> **T**: How many of you got to try it?
> [Hands go up]
> **T**: Did you? Did you follow that path?
> [slight discussion]
> **T**: What happens when you stand still?
> **Ss** (quickly): It stays the same
> **T**: It stays the same, makes a straight line. [T gestures horizontally with her arm]
> **T**: Where does it tell you on the graph that you're about a meter away from the motion detector?
> **S**: Up and down. [Student motions vertically with her arm]
> **T**: OK, and what's that axis called?
> **S**: The y.
> **T**: The y-axis. So, you're a couple of meters away from it. What happens, uh, how do you know you're running fast?
> **S**: Line is steeper [other students speak, too, this student gestures a steep line with her arm]
> **T**: It's steeper. OK. And when you're barely going? What happens?
> [Students mumble, inaudible. T says "it's just a little bit slow", and uses gesture to indicate a not-steep line.]
> **T**: Now, how can we tell? Lila was telling me she went up there and back. What happens to the graph?
> **S**: It goes up and down.
> **T**: OK. Up like this, and comes back down to where you started [gestures the up/down motion]. And, why is that?
> [**S** answers, inaudible]
> **T**: OK. [listens to student a little more]. OK. Over time, you came back to the same spot you started at, but it took time to do the motion, right?

<u>Analysis</u>:

During the review, Marilyn focuses on the main ideas of the previous day's activities. The graphs are discussed using gesture, rather than having a common visual to support the discussion. Marilyn asks for justification once, when discussing back and forth motion. Since the student answer was inaudible on the video, his/her contribution is unclear, but it is clear that Marilyn listens and attempts to re-voice it. The explanation, though, is imprecise, with no reference to a corresponding graph.

5.3.1.2 Introducing episode

After a student reads the top of page 24, the class discusses the meaning of the words *swamp* and *quicksand*. They then discuss the first activity:

> **T**: Don't run Wendella yet. Let's talk about this a little bit. OK, listen. What about the first segment that's on there, can you see that first segment? [T gets a student to move the cursor on the projected screen to point to the first segment]. There you go. That first segment, that first segment that he's running [determines it's minutes, not seconds], the first minute that he's running, what's he doing or where is he during that time?
> **S**: Road
> **T:** He's probably on the road. Right? We don't know what he's doing or anything on the road, but you're fixing to make that clear to us, because we're going to write a story. Now the next section, what's happening there?
> **S:** She's in the swamp.
> **T:** You think she's in the swamp? Possibly. Right? Why would he be in the swamp here?
> [Student answers, inaudible]
> **T:** OK. And I want you to, we're going to make up a story about this. OK, and what about this next little section? What's happening?
> [One student says Road, others say quicksand]
> **T:** You think he's in the quicksand? And then what happens?
> [Students can be heard saying road]
> **T:** OK. So, following that sequence, I want you to write a little story. Put some details in. Where was she going? Work alone on this. And then we'll run it and see if that's true. I may have one of you come up and write it. So make sure it sounds pretty good.

<u>Analysis</u>:

This is typical of Marilyn's introduction of the first exercise of a lesson, based upon observations of lessons 5, 7, and 8. During observations, the first page or more of a lesson was always enacted as a class activity, without any individual exploration. No particular student is ever called upon, and often the same student or students call out all the answers. If a wrong answer is offered, it is almost always ignored, as is the case in this example when a student calls out “road” while others are suggesting “quicksand”.

5.3.1.3 Follow-up episode

Having established the sequence of Wendella’s travels as a class, students were then given time (3 ½ minutes) to write individual stories. Afterwards, one student shares his story at Marilyn’s request, and since no one else volunteers to share, Marilyn starts to direct attention to the next page. She then remembers the simulation software:

> **T**: We can come back to that, but the main thing I want you to see is that he was on the road, then swamp, quicksand road. OK. Let’s go to the next page. You can come back to that in a little bit. But I don’t want to spend a whole lot of time on that. Let’s look at, oh first of all, let’s, go ahead and start that simulation
> T: Watch Wendella. [pauses as students press play] See what happens. Does it follow your story? [students laugh]. OK, see what happens? See where Wendella is running fast? Do it several times just to show. Just to see where he’s going and what he’s doing. [pause]. OK? Also, remember if you push the key step, what happens when you push step? Reset and push step. [Camera shows students stepping through the simulation]. It divides his trip up, doesn’t it, into each segment?
> [Students are running Wendella and using the step function as T speaks]
> **T**: So, that graph tells a story.

<u>Analysis:</u>

Marilyn once again reiterates a big idea of the lesson: “that graph tells a story”. But also, this excerpt is a typical example of Marilyn’s use of the software. The simulation software is used, but it is not a central focus within the activity; in fact in this case, it appears to be used as an afterthought. The students may or may not have compared the motion to their stories; since the correct motion was agreed upon ahead of time, there is little need. In general, the class uses the software sparingly as an observation tool, rather than as an individually based exploration tool. It is interesting that Marilyn encourages use of the ‘step’ function in this case, but does not suggest its use at any other time during the 3 days of observation.

5.3.1.4 Introducing episode

Marilyn then goes over activity #2A with the entire class, stating aloud the correct answers. Note that the graph of activity #2A does *not* have a corresponding simulation. There is a picture of page 25 projected as an overhead during this discussion, but Marilyn does not write down the answers. [On the two subsequent observation days, Marilyn does write down the answers as the class discusses the first 2 pages of Lesson 7 and the first page of Lesson 8]. In general, the answers students call out are correct, but Marilyn does acknowledge and encourage a discussion on whether Wendella spent two or three minutes in the quicksand:

> **T**: [pointing to graph] What’s happening here?
> **Ss**: Quicksand
> **T**: He’s in the quicksand
> **S1**: For 2 minutes
> **T**: For 2 minutes
> **S2**: *Three* minutes
> **T**: Is it 2, or 3?
> [Students can be heard saying 2 and 1]
> **T**: OK, why is it just two and not three?
> [Different students call out, T directs her gaze to S3 in particular]
> **S3** [gesturing as if she is counting along a horizontal line]: One, two, three, so that’s 2.
> **T**: OK. He goes, from zero to one he was running, and then from one to three, he was in the quicksand.

The episode continues with the start of activity #2B, with Marilyn explicitly writing the distance and time of the first segment on the overhead slide, as described below:

> **T**: OK. So what was her speed?
> [Pause. One student answers quietly]
> **T**: OK. 300 meters per minute, right? And how can we write that?

> **S**: over one.
> **T**: OK. over one. [T writes 300/1 on overhead]. 300 over one, or 300 meters per minute. OK. Now, what can we do with the second leg? I want you to go through and do the same things with each one of those sections.

Students immediately start asking questions about the next segment (in the quicksand), and this is determined as a whole group as well.

Analysis:

Other than briefly pointing to the horizontal portion of the displayed graph at the beginning of the discussion, neither Marilyn nor the students referred to the common visual during the interchange concerning activity #2A. As in a previous example, Marilyn's re-voicing of the student's explanation is imprecise and without any explicit reference to the graph. When introducing activity #2B, as in many of her introducing episodes, Marilyn establishes a method of solution and wants students to follow the procedure as they continue. It appears from this and subsequent observations that the 'standard class procedure' for determining speeds is to write distance/time as a fraction and then reduce to a unit rate.

5.3.1.5 Working on Problem episode

Students then work on page 25 for 6 ½ minutes on their own. Marilyn roams the classroom, helping three different students determine the distance traveled in the last three graph segments. The assistance she gives is similar to the whole class discussion given in the following *Follow-up* episode.

5.3.1.6 Follow-up episode

Marilyn addresses the class:

T: Some of you are getting a little confused.

Having already determined the time of each segment as a class, they now determine the distance and speed as well. When discussing distances, Marilyn refers to the projected graph, starting with her finger on one endpoint of a segment, and following the line to the other endpoint, saying, for example:

> **T**: So, on the road, how many meters does he travel from 400 all the way to 1000?

Marilyn does not explicitly refer to the y-axis during the interchange, and makes vertical hash marks at each endpoint of the various segments. She reads off many of the y-values herself. As the distances are determined, Marilyn writes each speed as a fraction near the corresponding segment in the graph of figure A: 300m/1 min, 0m/2 min, 100m/4 min, etc. Several students are calling out the correct answers and many respond positively when Marilyn asks if they now understand.

5.3.1.7 Working on Problem episode

Students are once again given time to work independently. This time continues to the end of class (12 ½ minutes). During this time, some students were ready to start working on page 26 of the workbook, which includes a graph representing the character Wendella moving both forward and backwards. This later activity does not get the long introduction of the earlier problems, but just a quick interjection as students work independently:

> **T to class**: And this one is very similar, guys, Remember what you did on the CBR Friday. Shh, listen. Remember what you did on the CBR Friday, and this, could, uh, help you a little bit with this graph. So go to that next page and look at it.

The workbook instructs students to first run the software file Wendella3.smw. When the file is run, Wendella the dog moves corresponding to the graph on page 26. Below is a transcript of the impromptu class discussion that took place after some students ran the file:

> **A student (off-camera, probably S1)**: Is it supposed to turn around like that?
> **S2**: She goes up and then she turns around and goes backwards again.
> **T**: Well, and what did you all do on the CBR?
> **S1** [gesturing a "V" (*not* an inverted "V" like the current graph)]: Yeah, but <inaudible>
> **S2**: But I thought she couldn't go backwards because that would make time go backwards.
> **S3** [off-camera]: Yeah.
> **T**: There's still time. Time is still passing by.
> **S1**: But it's going down and then this way [gesturing down and then across, as she speaks], so, <inaudible> she's going back [gesturing across in the opposite direction]
> [A student off-camera, perhaps S3, speaks over the end of what S1 says. He is inaudible other than the words 'going backwards']
> **T** [also speaking over the end of what S1 says]: What might have happened?
> **S1** [laughing]: He lost is bone.
> **T**: OK. He lost his bone, and what did he go do?
> **S2**: He went back to go get it.
> **T**: He went back to get it. Think about that. Good.

Although Marilyn works further with some students individually, this was the only group discussion that occurred in the classroom concerning this workbook exercise. Class continues with students working in the workbook either individually or in their groups. Marilyn encourages one group of students to elaborate in their story for Wendella3:

> **T**: Give some details. Like <student> said, maybe she went back for a bone. Notice it's still steep, she's still running. What made her go back to 100 meters?

As class continues, one student asks about #3C on page 26. #3B asked: "What did Wendella do 6 minutes after starting this journey?" (Answer: Wendella went backwards). #3C asked: "How does the graph show this motion?"

> **S**: What does it mean "How does the graph show this motion?"
> **T**: This motion. [T points to the graph in the workbook, pointing along the 2nd and 3rd segments]. They're talking about going there and back [T draws an inverted 'V' in the air]. How does the graph [T points to the computer screen, then moves the student's mouse]. See? Look. [T clicks the mouse, then moves the mouse some more and clicks again. S watches screen].
> **T**: Now this part right here. [T points to screen (not visible on camera), and draws an inverted 'V' on the screen with her finger].
> **T**: How does the graph show that?
> **S**: As the graph is going down, she's going backwards?
> **T**: OK. yes. [Starts to walk away] You can tell me that.

Marilyn works briefly with other individual students and class ends with students still working on the 3rd page of the lesson (out of 5 total pages).

Analysis:

Marilyn typically does not have a long introductory episode for activities on later pages of a lesson. She appears, over the course of the lessons, to spend a great deal of whole class time on the initial material, and students work mostly independently from then on.

Although students from different areas of the classroom participated in the discussion about software file Wendella3, it is not clear that everyone had run the simulation and was thus able to participate in the discussion. Marilyn attempted to connect this experience with the student's experience with the CBRs ("and what did you all do on the CBR?"), but this connection is not explored; Marilyn simply states that time is not going backwards ("There's still time. Time is still passing by"). She accepts and encourages justification on why the character might have gone backwards (to get his bone) but does not respond at all to S1's comments about the CBR experience or this same student's attempt to connect the graphical representation to the character's motion. It would appear that little or no consideration is given to using the simulation resource as a means of addressing the students' confusion at this time, or at other times throughout the lesson. Again, this type of behavior appears to be quite typical of Marilyn's teaching of this unit. The simulation resource is used as the workbook instructs, but generally only under those explicit circumstances (although there are exceptions). Despite the simulation capability, graphs are usually interpreted statically. In this case, the graph may not be interpreted by all or most of the students.

Although the emphasis is on story elaboration, when Marilyn encourages one student to "give some details", in the process she points out another important aspect of the graph: the segment with a negative slope is still steep, which indicates the character, although moving backwards, is still moving at a rapid pace. Over the course of observations, there were other similar cases of Marilyn pointing out or helping students to see important aspects of the graphs in small groups. However, since most whole group work occurred toward the beginning of class, in general there was little or no later follow-up during whole group discussions, where the entire class could potentially benefit.

While working individually with a student on activity #3C, Marilyn appears to use the software to make a point. The screen is not visible on camera, but since she clicked on the mouse twice and the student watched the screen, it is likely she hit the reset and then the play button so the student could watch the motion once again. Marilyn's explanation is unclear, repeatedly referring to the inverted 'V' of the graph rather than the motion itself, which is not helpful in understanding what 'motion' the question is referring to. Despite this, or perhaps because Marilyn directs her attention to the correct portion of the graph, the student does seem to understand the question and suggests a reasonable response. Note also another potentially important issue: Marilyn herself is running the simulation, not the student. This type of behavior appears to be quite typical of her use of the software during such discussions. When helping a student, Marilyn often manipulated the software herself. Again, this behavior seems to reflect a more teacher centered style (see Cuban, 1993) characterized by teacher demonstration followed by student practice. In Marilyn's case, she often started the manipulations (showing the student how) and then let the student continue.

Class ends with students still working on the 3rd page of the lesson. The 4th and 5th pages, which are ultimately skipped completely, are resource-intensive activities that require students create a graph and test for accuracy by running the simulation. The final activities of lessons 4 and 7 are similar create & test activities, which Marilyn also skipped due to time.

Notice that the last whole group discussion was about activity #2B on page 25. There is no follow-up on any subsequent work. This was true on all 3 days of observation – answers to the first page or two were completed as a whole group, before any individual exploration, and little time was spent discussing activities after students had attempted them. Some interesting interactions and student observations occurred in small groups (for instance, the surprise when Wendella ran backwards), but these were not explicitly addressed with the entire class.

There is no indication that students received ongoing feedback on their independent work; Marilyn checked some but not all class work as she roamed the class.

Had it been a normal day (without the post-observation interview after class), it is possible, indeed likely that Marilyn would have used the overhead projector to display the workbook page and go over some answers during TAKS class, as she did on the 2nd day of observation when data collection continued through that time. This follow-up, by its design, would not include the students who do not attend TAKS class.

5.3.2 Perceptions and Reflections

Marilyn speaks quite positively about her classroom setup, with Marilyn stationed by a projection of the workbook page. After observing Marilyn teaching the unit, Trainer A praised this setup as well. Within the following interview excerpt, Marilyn expresses her belief that "regular math students" need to be focused or they may "just more or less guess at it … and write just anything down":

> **Q**: What kind of advice would you give a colleague?
>
> **Marilyn**: …. Advice-wise, I would probably suggest, I do like where the student runs the simulation and I'm in a different spot. Again, talking about the overheads and keeping them focused because especially with regular math people. Regular math students. I think everything, they really need to be focused. Otherwise, they're going to, they may get lost. Because I don't know that they can, I mean they can do it independently but I don't know if they really try that hard to do you know what I'm saying? Or I just think they need to really be focused on it. For the learning to really take place. Otherwise I feel like they may just more or less guess at it I guess you know what I'm saying and just write anything down and that type of thing. So you really have to have their attention during the activities. So that would be something maybe that I would suggest is just make sure that your room is set up properly I guess.

5.4 Comparison with Other Case-Study Teachers

In many ways, Marilyn's enactment of the SimCalc unit was comparable to the other case-study teachers. Class time focused on the workbook exercises, Marilyn discussed the big ideas of the lessons, and each student had individual access to the software. Her review of previous material appeared more thorough than many of the others; Gayle did not review at all during the three days of observation. One might argue that Marilyn could have improved class attempts at justification, in particular by referencing a commonly-viewed graph, but this was generally true in several of the other case-study classrooms as well. In fact, Gayle's class did not have a common visual at all, while Kate purposely focused students on their workbook during whole class discussion of unit material. Similarly, the lack of explicit focus on the software was not uncommon across some of the case-study classrooms, especially during whole class discussions.

As stated previously, what does stand out in Marilyn's enactment as being significantly different from the other case-study teachers can be described in terms of *time and material* and *class organization and level of directive teaching*. Data from the teacher's daily logs and analysis of the video data support these as distinctive features.

5.4.1 Time and Material

By Lesson 4, Marilyn began restricting herself to a one day per lesson regime, moving on each day regardless of circumstance. No other teacher was observed skipping material in order to align to such a schedule.

Analysis indicates that Marilyn did in fact spend less time on the material than most of the other case-study teachers, even if the TAKS class time is included. Table **10**, generated by information from teacher lesson plans and daily logs, indicates information on the time the case-study teachers had allotted (according to their lesson plans), and how much time they actually spent on the workbook activities. Days spent on teacher-selected supplementary activities and materials are not included in this analysis, but days spent on a combination of workbook and other materials are included, as well as time spent exploring the software. The '+' and '-' designations indicate that the days and total minutes spent could be a bit higher (+) or lower (-), depending on circumstances indicated in the teacher daily logs (explanations included below the table). The table does not include days in which the teacher indicated "there was an unusual occurrence that took up significant class time (e.g. fire drill, special assembly, administration or standardized test)", but if the teacher indicated some amount of workbook material was done that day, this was indicated with a '+'.

The column "Adding in TAKS class time" assumes Marilyn's class spent an additional 25 minutes per day on the workbook, starting, as Marilyn indicated in the interview, at the Lesson 3 activity *Controlling Characters with Equations.* This is a high estimate of time, since the TAKS class was somewhat less than 25 minutes.

Table 10: Time Spent on Workbook Activities

Teacher	Region	Planned days for workbook activities	Actual days spent on workbook activities	Math periods per day	Minutes per Math period	Total minutes spent on workbook activities	Adding in TAKS class time
Kate*	A	Not Avail	6+	1	75	450+	
Marilyn*	A	13	10-	1	45	450-	625-
Wendy	A	17	25	1	50	1250	
Gayle*	B	14	16+	1	45	720+	
Sharon*	B	Not Avail	13+	1	55	715+	
Jackie & Samuel	C	12	13	1	63	819	
Carly*	C	10	10-	2	40	820-	

* Explanations:

Kate: Also spent some time on Lesson 1 the day of pre-test
Marilyn: One day on a shortened schedule
Gayle: One unusual day, students who "made it back to class" worked on an activity
Sharon: One unusual day, students still spent time on an activity
Carly: Indicated extra materials & activities included on several days. Also specified only 20 minutes on final (11^{th}) day, so 20 minutes is added into total

The table demonstrates that Marilyn's plan, in terms of days, was similar to the other teacher's plans, although on the short side since her Math time per day is short. But, as can be seen from the table, the other teachers extended their planned time while Marilyn did not. As a result, the five higher level students in Marilyn's class, who did not attend the TAKS classes, spent less time on the unit activities than any of the other case-study students. Even those students attending TAKS class spent less time than all but one other class. (This other class -- Kate's -- was a high-achieving class of Algebra I students, yet had a teacher-level gain score below both the treatment average and the case-study sample average.)

When discussing Marilyn's five higher level students, it is important to point out that 'higher level' is a comparative term. Although specific students were not followed in this study, Table **11** below shows that only two students in Marilyn's class scored above the treatment average on the pre-test, and only one of these was well above average. Furthermore, most of those who did fairly well pre-test (scored close to treatment average) scored well below the treatment average on the post-test. In fact, the highest M2 gains in Marilyn's class were achieved by students whose pre-test scores were not only below the treatment average, but below the class average as well. Thus, despite Marilyn's beliefs to the contrary, the stronger students might have been disadvantaged by missing the TAKS class portion of the unit.

Table 11: Student raw scores for Marilyn's class

	Total student assessment score - pretest (student-level)	Total student assessment score - posttest (student-level)	Difference score student total (student-level)	Difference score student M1 (student-level)	Difference score student M2 (student-level)
	5	4	-1	-1	0
	5	7	2	2	0
	7	11	4	0	4
	8	13	5	-1	6
	9	7	-2	-3	1
	9	8	-1	-4	3
	9	12	3	2	1
	9	17	8	1	7
	10	11	1	-1	2
	11	15	4	2	2
	12	10	-2	-1	-1
	20	26	6	3	3
Class average	9.5	11.8	2.3	-0.1	2.3
Treatment Teacher-level average	11.2	17.7	6.5	2.0	4.5
Treatment Student-level average	11.9	18.9	7.0	2.2	4.8

Not surprisingly since she spent less time, Marilyn also skipped more material than the other teachers. Table **12** reflects information obtained from the teacher’s daily logs on what workbook pages were skipped.

Table 12: Pages skipped

Page # / Teacher	16-19	22	23	27	28	29-31	32	33	37	38-39	40	41	42-48	49-50	51	52
Kate			S		X		X				X		X	X	X	X
Marilyn			X	X	X	X	X		X		X	X	X	X	X	X
Wendy			S	X	X	X	X		S				X	X		X
Gayle		X														
Sharon																
Jackie								X		X	X	X	X	X	X	X
Samuel								X		X	X	X	X	X	X	X
Carly	X*						S							X	X	X

X indicates this page was skipped by the entire class
S indicates that some students worked on this page, and some did not
X*: Post-unit log indicates “this was assigned & asked to be finished as an on-going assignment whenever kids had time in computer lab, but most never got to go back”

It is clear that many of the teachers skipped pages (and whole lessons) close to the end of the unit. However, Wendy and Marilyn were the only ones to skip all of Lesson 6 (pp.29-32) and the final pages of Lessons 4, 5, and 7. The final lesson pages were resource-intensive activities allowing students to interact with the dynamic features of the SimCalc software. Although this lack of access might be a factor in Marilyn’s low student gains, it is important to point out that at least some students in Wendy’s class were similarly limited and yet the average gain score in Wendy’s class, made up entirely of low-ability students, was twice that of Marilyn’s mixed-ability class.

Wendy spent much more time on the material she *did* cover than did Marilyn, which speaks not only to the issue of time but also to lesson coherence. Pigeon-holing each lesson into a 45-minute session may have left students unable to follow the thread of ideas through the unit. This concern may have been exacerbated by other distinctive aspects of Marilyn’s enactment: class organization and level of directive teaching.

5.4.2 Class Organization and Level of Directive Teaching

All classes went through the activities of each lesson sequentially as indicated in the workbook. However, as already indicated, in Marilyn's case the activities towards the end of the lesson were often skipped due to time constraints. A good amount of class time was spent on the beginning exercises, since Marilyn went through the first page or two of each lesson as a class. This introduced students to the answers before any individual exploration. Furthermore, little time was spent discussing activities *after* students had attempted solving them.

Evidence to support these claims can be seen through videotape analysis of the observation days. First, Table **13** shows the percentage of time spent in each classroom in *reviewing, introducing, students working on problem, and follow-up* episodes, during the days of observation. There are two entries for Marilyn, the first *not* including the Observation Day 2 TAKS class, and the second including this observation data. When calculations are restricted to data including Marilyn's entire class (i.e., no TAKS class data), Marilyn spends close to 50% of her time *introducing* material to her class. During this time, Marilyn most frequently led students through workbook exercises, writing the answers on a copy of the workbook page displayed through an overhead projector. Even if the TAKS class data is included, her introduction time is still 44%, while all but one of the other case-study teachers spent less than 16% of their time in *introducing* episodes (Jackie and Samuel's joint class is not included in this table due to insufficient observation time).

Table 13: Percentage of time spent in different types of classroom episodes, based on 3 days of observation

Teacher	Region	Review	Intro	Work On Problem	Follow Up		percentage of "whole group" time spent in Intro
Kate	A	1%	5%	79%	15%		24%
Marilyn, including Day 2 TAKS class	A	2%	44%	45%	8%		81%
Marilyn, *not* including Day 2 TAKS class	A	3%	49%	44%	5%		87%
Wendy	A	3%	35%	50%	13%		70%
Gayle	B	0%	15%	71%	14%		52%
Sharon	B	3%	14%	65%	18%		40%
Jackie & Samuel	C	**	**	**	**		**
Carly	C	9%	13%	58%	20%		31%

****** : Insufficient data

Also, while Marilyn's *reviewing* percentage is comparable to most other case-study teachers, her *follow-up* time is the lowest. During regular class time, Marilyn spent only 5% of class time discussing workbook material *after* all students had had a chance to work on the problem themselves. This figure increases if the TAKS class data is included, but the percentage remains low, and six of her students did not attend TAKS sessions (the five higher level students plus one special education student).

It is also important to point out the way Marilyn managed her whole group time, i.e., the time spent discussing ideas with the entire class. This would be the total of the reviewing, introducing, and follow-up episodes. As the table above indicates, whether the TAKS class is included or not, Marilyn spent a higher percentage of whole class time on introductory episodes than the other case-study teachers; spending over 80% of her whole class time introducing materials rather than in review or follow-up discussion.

5.5 Marilyn's Distinctive Features

Marilyn's enactment of the materials was distinctive in terms of time, material, class organization and level of directive teaching. Excluding the time spent during TAKS class, which did not include six of her students, Marilyn spent less time on the unit than any other case-study teacher. Even including the TAKS class, she spent less than all but one. Marilyn also skipped more material within the unit than any other case-study teacher, including all of Lesson 6. In terms of class organization, based on 3 days of observation she spent a much larger percentage of class time introducing the material to the students and a much smaller percentage of time in follow-up, compared to the other case-study teachers. Her percentage of time allowing students to work independently was also lower than the other teachers; since her total time on the unit was low as well, this might imply a significant difference in terms of opportunity for independent work. Furthermore, Marilyn's approach was highly directive. At the beginning of each observed lesson, there was a long introductory episode in which she “walked” the students through the first page or two of the lesson, helping them determine the workbook answers and often writing the answers on an overhead. This introductory approach was not observed in any other classroom.

Chapter 6: Gayle

Gayle's gain score is the highest in the case-study sample and is above average for the entire treatment sample, despite teaching that seemed generally focused on formulas and procedures. These results, coupled with Gayle's low pre-unit MKT score, provide motivation to study her situation and unit enactment to look for potential reasons for this success.

6.1 Comparison of Class Characteristics

While Marilyn's class characteristics were fairly easy to compare to the case-study sample in almost every aspect, Gayle's class is more difficult to characterize. Refer to ***Table* 14** below (a copy of *Table* **8**):

Table 14: Description of case study classrooms

Teacher	Class size	Class description (taken from teacher log)	Title 1 school?	% free lunch
Kate	21	High achieving	?	30.4%
Marilyn	12 (?) [14 in observation video]	Average achieving, High achieving, Low achieving, LEP/ESL learners, Special ed, 2 students who are mainstreamed	yes	65.7%
Wendy	17	Low achieving, LEP/ESL learners, 7 special ed, all mainstreamed with modifications	?	68.8%
Gayle	9	Average achieving	yes	44.0%
Sharon	15	only 8th class in school, all ability ranges in this classroom, including three spec. ed students and two borderline spec ed students	?	43.9%
Jackie	12	High achieving, LEP/ESL learner, Pre-AP, TAG, Special ed (just one)	yes	91.7%
Samuel	13	Average achieving	yes	91.7%
Carly	22	Average achieving, special ed (inclusion)	?	39.1%

The socio-economic status of Gayle’s school did not stand out within the case-study sample, with three other schools of similar or higher SES. But Gayle’s class did have certain advantages, the effects of which are unclear.

Gayle had an average achieving class, which may have given her an edge compared to Wendy’s low-ability class or even the mixed ability classes of Sharon or Marilyn. But Gayle’s overall gain score also surpassed Kate’s high achieving Algebra I class, as well as Jackie’s class, described in Jackie’s pre-unit log as high-achieving and

TAG (talented and gifted), although pre-unit test scores for this class were below average.

Gayle also may have had a potential advantage due to a small target class of only nine students. Carly's class was quite large in comparison (22). Samuel's class of 13 was not that much more than Gayle's, but since Samuel was co-teaching with Jackie's class of 12, the combined class was significantly larger. Jackie and Samuel also had additional students who were moved into the class after the pre-unit test and were thus not an official part of the study. Kate also had a much larger class (21), although her co-teacher helped assist students during small-group and individual work sessions.

Within the case-study sample, Gayle's class was most similar to Carly's, Jackie's and Samuel's classes in terms of student ability (refer to ***Table* 15** below), although even these comparisons are difficult. Carly also described her class as average achieving, but her class started with a much lower pre-unit average test score (7.5) than Gayle's (11.3). Jackie described her class as *high*-achieving, but her average pre-unit test score (9.6), while higher than Carly's, was still below the case-study average and well below Gayle's class. Gayle's average pre-unit score was most similar to Samuel's (11.5), another reportedly average achieving class. Still, the socioeconomic status of Gayle's class was much higher than Samuel's (and Jackie's), using free lunch as a measurement (44% free lunch vs. 97%). On the other hand, Gayle's MKT score was much less than all three of these teachers, whose scores were all in the highest quartile (while Gayle was in the lowest).

Table 15: Teacher-level pre-test results for case-study sample

Teacher	Class average pre-test score	Pre-test M1 (teacher level)	Pre-test M2 (teacher level)
Kate	20.8	11.3	9.5
Marilyn	9.5	6.2	3.3
Wendy	5.4	3.6	1.8
Gayle	11.3	5.1	6.2
Sharon	10.3	6.1	4.2
Jackie	9.6	6.8	2.8
Samuel	11.5	7.2	4.4
Carly	7.5	4.4	3.0
case study average	10.7	6.3	4.4
Treatment average (teacher level)	11.2	6.9	4.3

Although these issues of class-size, SES, and student (and teacher) ability levels are unfortunately ever-present in these comparisons, there is reason to believe that any advantages Gayle might have had in these respects may not entirely account for her comparative success, especially when comparisons are extended to the overall treatment sample: Gayle's average-achieving class in a Title 1 school, with a pre-unit average test score very close to the treatment teacher-level average, had above-average gain scores (.4 of a standard deviation above the treatment average). Thus despite an average-achieving class in a less-advantaged district with a 2^{nd}-year teacher with low MKT whose enactment seemed unremarkable, student gains were above the average treatment classroom.

The above treatment-level comparison doesn't take into account Gayle's small class size. However, two classes among the entire treatment sample were similar to Gayle's in terms of class-size and student ability (see Table **16** below). Gayle's class is most similar to T1's class. T1 did have one low ability student, but had two high ability students (while Gayle had just one), and T1's average pre-test score was slightly above Gayle's. Furthermore, T1's school was much lower percentage of free lunch (implying higher SES), and his/her MKT score was more than twice Gayle's, putting him/her in the highest quartile for MKT. And yet despite these advantages, Gayle's average gain is much higher. T2's class is also similar, with gain scores similar to T1's, again much lower than Gayle's.

Table 16: Small treatment classes of predominantly average-achieving students

Teacher	MKT quartile	% free lunch	total students	# Low	# Med	# Hi	Class average pre-test score	Class average post-test score	Class average gain
Gayle	1st	44	9	0	8	1	11.3	19.11	7.78
T1	4th	13	9	1	6	2	11.9	17.11	5.22
T2	1st	57	11	2	6	3	9.6	14.91	5.27

Unfortunately there is no observation data for either of these classrooms, since they were not part of the case-study sample. However, their scores demonstrate that Gayle's success may not be entirely due to having a small class of average achieving students. These classrooms were similar in these respects yet did not have similar average gains.

What was different about Gayle's classroom enactment that might shed light on the class's higher performance? It may well be that Gayle's success is at least partially, if not primarily, due to how the unit was enacted. Marilyn's case suggests that the issues of 1) time and material and 2) class organization and level of directive teaching are influential with respect to student performance. Before describing Gayle's enactment in detail, it is helpful to consider these attributes as they pertain to Gayle. The following section provides an initial analysis, following these factors in a manner similar to our analysis of Marilyn. The subsequent section provides discussion and motivation for a deeper analysis.

6.2 Initial Analysis of Important Attributes

6.2.1 Gayle's classroom

During each day of observation, Gayle started class by continuing in the workbook wherever class had previously left off. On the day preceding the first observation day, students had been assigned the last page of Lesson 4 for homework. Since most students had not completed the assignment, Gayle had them complete the workbook page during class, and then check their work using the software (as indicated in the workbook), which had been planned for class time anyway.

Once this activity was complete, Gayle moved the class on to lesson 5. Students completed the first page, and Part A of the second page, during this class period. The following day, class began where they had left off the day before, Part B of the 2nd page of Lesson 5. Class continued sequentially through the lesson, with students working on the 4th page by the end of the class period. When class reconvened on the last day of observation, class continued where they had left off, finishing off the 5th (last) page of lesson 5 and then moving on to lesson 6. Class ended with students working on the 3rd page of lesson 6. From Gayle's daily log, it is clear this pattern continued. Class periods did not correspond to a particular lesson, but rather workbook activities were worked through sequentially as time permitted. Lesson 6 was completed the following day, along with most of lesson 7. During the next class session, lesson 7 was finished up, lesson 8 completed (lesson 8 is only 2 pages long), and work started on lesson 9. Lesson 9 and lesson 10 were completed on subsequent days.

While Gayle's original lesson plan scheduled 14 days on workbook materials, her enactment extended this time to 16 days (plus an unusual day where class time was extremely limited but some students worked on unit materials). In her interview, she mentions that some students needed more time and so it was not always possible to stick with the lesson plan timing (recall that all five 8^{th} grade classes were using the unit materials).

According to her daily log, Gayle's class only skipped one page in the entire workbook. During the three days of observation, no problems or activities were skipped; Gayle allowed class time for the students to work on each workbook problem.

In fact, episode analysis indicates that Gayle allowed 70% of class time for individual or small group work during the days of observation. The rest of the time was divided equally between introducing new activities and follow-up episodes. Gayle did not review material from previous lessons in any organized way, i.e. anything that could have been considered review was said as a passing remark. Activities were *not* completed as a class during introducing episodes, but follow-up episodes covered almost every part of every activity. These whole class discussions provided answers and some amount of reasoning for each problem, although reasoning was generally based on rules or formulas, and there was no common visual available during this time or at any time during the three days of observation.

6.2.2 Comparison with Other Case-Study Teachers

6.2.2.1 Time and Material

Table 10 from the previous chapter showed that Gayle spent more time on the unit than Marilyn, but only an average amount of time compared to the other case-study teachers. She did, however, get through more material than most of the teachers. As Table 12 from the previous chapter indicates (re-printed here as ***Table* 17**), most other teachers started to skip quite a bit of the workbook towards the end of the unit, but Gayle did not.

Table 17: Pages skipped

Page # / Teacher	16-19	22	23	27	28	29-31	32	33	37	38-39	40	41	42-48	49-50	51	52
Kate			S		X		X				X		X	X	X	X
Marilyn			X	X	X	X	X		X		X	X	X	X	X	X
Wendy			S	X	X	X	X		S				X	X		X
Gayle		X														
Sharon																
Jackie								X		X	X	X	X	X	X	X
Samuel								X		X	X	X	X	X	X	X
Carly	X*						S							X	X	X

6.2.2.2 Class Organization and Level of Directive Teaching

Gayle fit lessons to class time quite differently from Marilyn. Marilyn did not want to extend lessons into the next day because, as she noted, she felt another entire class session would not be necessary. Although she did not explicitly explain her reasoning, Marilyn did not seem to want to expose her students to two separate lessons in the same class session.

In contrast, this did not seem to be an issue for Gayle. Gayle's class worked through all the material activity by activity moving from lesson to lesson as needed, rather than being restricted by the beginning or end of a class session. This is not a distinctive characteristic of Gayle's classroom enactment; Kate and Sharon both conducted their classrooms similarly, at least during the three days of observation.

As with Marilyn, it is important to look at Gayle's class time organization. Although Gayle spent no time reviewing previous material, Table 13 of the previous chapter (re-printed below as ***Table* 18**) indicates that the reviews in every class except Carly's were quite short, only 2-3% of their total class time. Gayle spent a much smaller proportion of her time introducing activities and a somewhat greater proportion in follow-up compared to Marilyn, more in line with most other case-study teachers.

Table 18: Percentage of time spent in different types of classroom episodes, based on 3 days of observation

Teacher	Region	Review	Intro	Work On Problem	Follow Up		percentage of "whole group" time spent in Intro
Kate	A	1%	5%	79%	15%		24%
Marilyn, including Day 2 TAKS class	A	2%	44%	45%	8%		81%
Marilyn, *not* including Day 2 TAKS class	A	3%	49%	44%	5%		87%
Wendy	A	3%	35%	50%	13%		70%
Gayle	B	0%	15%	71%	14%		52%
Sharon	B	3%	14%	65%	18%		40%
Jackie & Samuel	C	**	**	**	**		**
Carly	C	9%	13%	58%	20%		31%

** insufficient data

While Gayle spent less total time than some classrooms, she also spent a higher percentage of that time allowing her students to work independently or in small groups. If we assume those percentages remain constant over the course of the unit and then extrapolate from that assumption over the entire time each class spent on the unit, we would *project* that Gayle's students most likely had more time to work independently on the materials as any other class except Wendy's low achieving class (see **Table 19** below). Of course, these figures cannot be taken literally, but since each teacher's class organization did not change drastically from day to day over the three observed days, it is may be reasonable to assume these numbers have some credibility as estimates.

Table 19: EXTRAPOLATED ESTIMATE of student independent time

Teacher	**Region**	**Work On Problem**	Total minutes spent on workbook activities	**Estimated time Working On Problem**
Kate	A	79%	450+	355+
Marilyn, *not* including Day 2 TAKS class	A	44.1%	450-	199-
Wendy	A	49.6%	1250	620
Gayle	B	70.5%	720+	508+
Sharon	B	65.3%	715+	467+
Jackie & Samuel	C	**	819-	**
Carly	C	58.1%	820-	476-

*** Insufficient data*

6.3 Motivation for Deeper Analysis

The following two tables summarize a comparison of Marilyn, Gayle, and the other case-study teachers in terms of time, material, organization and directive teaching.

Table 20: Summary Comparisons, Time and Material

	Marilyn	**Gayle**	**Other teachers**
Time	Low-range (450 minutes, 625 min for students attending TAKS class)	Mid-range (720+ minutes)	Ranged from 450-1250 minutes, mostly 715-820
Material	Skipped more than anyone else Added “extras”	Only skipped one page of workbook No “extras”	Most skipped many pages

Table 21: Summary Comparisons, Class Organization and Directive Teaching

	Marilyn	**Gayle**	**Other teachers**
Class Organization	3% review 49% introducing 44% student work 5% follow-up Lesson-a-day	0% review 15% intro 71% student work 14% follow-up Activity-by-activity	Mostly 1-3% Mostly 5-15% 50–79% 13-20% Various. No lesson-a-day
Level of Directive Teaching	"Walked" students through good portion of material before allowing independent work Answers on projected overhead during "walk-thru"	Provided instructions, formulas & evaluations that often circumvented use of software and graphical representations.	No similar behaviors

This comparison indicates that Gayle is different from Marilyn in almost every respect observed and analyzed. Compared to Marilyn, Gayle spent a good deal more time and covered much more material. The data on class organization indicates that Gayle spent a good deal less time introducing activities to her students than Marilyn (15% vs. 49%), but instead gave her students more independent time (71% vs. 44%) and more time spent on follow-up discussions (14% vs. 5%). Gayle did not restrict herself to a lesson-a-day format as did Marilyn, but allowed lessons to extend into as many class periods as she deemed necessary. As for directive teaching, Gayle did direct her students to more algebraic solution methods, but she did not "walk" her students through the material. She did not provide students with answers; students were expected to do the work themselves. This was often not the case in Marilyn's class, where the extensive up-front whole group work allowed some students to simply copy down activity responses.

Furthermore, Gayle not only gave students more *independent time* than Marilyn, but as the class organization percentages might imply, Gayle also allowed students more *independent time to think about the problem* than Marilyn. For instance, on the 2nd page of lesson 5, Marilyn discussed the answers to part A before students made any attempt to do the work independently, and then allowed only 6 ½ minutes for students to work individually before she conducted a whole class session and supplied the answers to part B as well. In contrast, Gayle simply read the problems to the students (also providing an empty table as a handout "to make sure you keep everything organized" for part B), and allowed 23 minutes for the students to work individually or within their groups before discussing the answers to parts A and B during a whole group follow-up discussion. This contrast between the two teacher's approaches was consistent throughout the days of observation. Gayle also provided more follow-up time than Marilyn, thus providing students with feedback *after* they had attempted the material.

Although very different from Marilyn, Gayle's enactment is in general not distinctive from the other case-study teachers. While Marilyn's overall time spent on the unit was in the low range, Gayle's was mid-range for the case-study sample. Most aspects of class organization compare similarly: while distinctively different from Marilyn, the percentage of time spent in introductory and follow-up episodes in Gayle's classroom was similar to most other case-study teachers. Even her lack of review episodes, which might be considered cause for concern, is not too different from the 1-3% review time allotted by most other case-study teachers

Still, the above tables of comparison, considered with the extrapolated estimates from the previous section, do indicate that Gayle's class completed more material and had as much if not more independent time than most of the other case-study teachers. In these respects, Gayle was on the opposite end of the spectrum from Marilyn, and thus these might be especially important attributes in understanding Gayle's comparative success. But a deeper analysis is in order, as there are still many questions concerning Gayle. Observations indicated that Gayle tended to provide students with instructions and formulas, and to evaluate student work rather than allow students to explore their solutions through the software. These tendencies leave questions about Gayle's enactment, especially when specifically compared to Sharon and Carly. **Table 22** represents a summary of the comparison, with an explanation following:

Table 22: Comparison of Gayle, Sharon, and Carly

Gayle	**Sharon**	**Carly**
Allowed substantial time & student independent time	Allowed substantial time & student independent time	Allowed substantial time & student independent time
Completed most of workbook	Completed all of workbook	Only skipped portions of lessons 3 & 10
No review, follow-ups covered answers	Short reviews, more conceptual discussion	Extensive review, follow-ups focused on concepts & connections
Little emphasis on graph interpretation or software features	Emphasized graph interpretation and use of software features	Emphasized graph interpretation and use of software features

Certainly, Marilyn's case suggests allowing sufficient time, providing feedback, and refraining from directing the flow of all ideas may be important attributes for success. But Sharon in particular enacted the unit in a manner similar to Gayle in these respects. Sharon and Gayle were the only teachers to complete most of the workbook, they both introduced each activity without giving explicit answers, and both allowed a good deal of independent time before follow-up whole class sessions that discussed the correct answers. Sharon may have allowed students somewhat less independent time, so substantial independent time may in fact be an important attribute. But this differential is based on a 3-day observation window, not a complete analysis of their teaching time. Furthermore, in contrast to Gayle, observations suggest that Sharon gave more emphasis to graphical representations and encouraged students to use the software more often and seemingly more productively than did Gayle. Based on observations and interviews where Sharon expressed an understanding and appreciation of the unit and materials, there was reason to expect her class to be successful as or more successful than Gayle's. Despite these observations and expectations, although the two class's average pre-test scores were fairly close, Gayle's overall average gain score was 2.6 points higher than Sharon's.

Gayle's slightly superior performance over Carly was also especially surprising. Carly only skipped portions of lesson 3 and lesson 10, still completing activities that covered the main ideas of those lessons. Although our time estimates for Carly are upper bounds (because she indicated use of other materials as well), Carly still most likely spent as much if not more time on the unit materials than Gayle. However, based on observations, Carly's enactment was different from Gayle's in ways one would expect to be significant. Carly conducted significant reviews of the previous day's main ideas at the beginning of each morning session, and her follow-ups focused not on specific answers but on conceptual understanding, most specifically the connections between motion and its representations (including mathematical explanations for these connections), as well as connections between lessons, such as analogies between motion and the accumulation of money. These types of connections were seldom if ever present in Gayle's enactment.

By looking more carefully at the post-unit test results of these three classrooms (see ***Table* 23** below), it is possible to interpret them in a manner more in line with expectations. Gayle, Sharon, and Carly's classes are listed first for easy comparison. Although Gayle's overall average gain is above the treatment average and surpasses that of Sharon and Carly, her M2 gains are in fact *below* treatment average and below Sharon's and Carly's classes as well. In fact, Gayle's M2 gains are less than most of the case-study teachers, all except Wendy's class of low-achieving students and Marilyn's class.

Table 23: Pre- and Post- test results (Gayle, Sharon and Carly listed first)

Teacher	Avg pretest score	Avg posttest score	Avg M1 pretest	Avg M1 posttest	Avg M2 pretest	Avg M2 posttest	Avg gain	Avg M1 gain	Avg M2 gain
Gayle	11.3	19.1	5.1	9.2	6.2	9.9	7.8	4.1	3.7
Sharon	10.3	15.5	6.1	7.1	4.2	8.5	5.2	0.9	4.3
Carly	7.5	15.0	4.4	7.0	3.0	8.1	7.6	2.5	5.0
Kate	20.8	26.0	11.3	12.4	9.5	13.7	5.2	1.1	4.1
Marilyn	9.5	11.8	6.2	6.1	3.3	5.7	2.3	-0.1	2.3
Wendy	5.4	10.1	3.6	5.5	1.8	4.6	4.7	1.9	2.8
Jackie	9.6	16.1	6.8	8.4	2.8	7.7	6.5	1.6	4.9
Samuel	11.5	17.8	7.2	9.3	4.4	8.5	6.3	2.2	4.2
treatment average	11.2	17.7	6.9	8.9	4.3	8.8	6.5	2.0	4.5
treatment stdev	4.6	6.3	2.2	3.0	2.5	3.4	3.1	1.4	1.9
control average	11.4	14.2	6.6	8.2	4.8	6.0	2.7	1.6	1.2
control stdev	5.3	5.4	2.6	2.5	2.8	3.0	2.2	1.2	1.5

This table shows that a significant portion of Gayle's average gain comes from student's performance in the M1 category. This was not typical in the treatment classes, as can be seen by noting that her M1 gain is more than a standard deviation above the treatment average. In fact, Gayle's class was the only treatment class in the overall 8^{th}-grade study whose average M1 gain surpassed its average M2 gain.

These observations do not diminish the success of Gayle's class, but do suggest a direction for deeper analysis while remaining focused on the categories deemed crucial in Marilyn's enactment. In terms of time and material, it is already clear that Gayle stands out as a teacher who provided students a good deal of independent time and managed to cover almost all of the unit material. But further study of other aspects of time allotment, as well as class organization and most especially the level of directive teaching, leads to new insights. The following sections explore these issues.

6.4 Time and Material

As already noted, Gayle had originally planned 14 days to cover the unit material, and extended that time by two days. These extensions were mostly in the early lessons of the unit; Gayle spent more than 2 class periods on Lesson 2 (2 periods planned), more than 3 periods on Lesson 3 (2 planned), and more than one period on Lesson 4 (1 planned). She also spent more than a class period on Lesson 6, but less than a class period on Lesson 8 (both planned as a one-day lesson).

More than a full class period was spent on the lesson 3 pencil-and-paper activity *One to Another*, originally planned as a homework assignment. Some students also worked on this activity another day (an "unusual day" not included in our time total) and Gayle also assigned homework from the unit on the final day this activity was covered (thus, students were likely assigned to complete the activity at home, focusing even more time on this work).

The activities in lesson 3 and lesson 4 focus specifically on translations between graph, table, equation, and narrative. Considered together, Gayle's class spent four full 45-minute class periods and two other partial periods (the day before and the day after the full periods) on these activities, as well as the "unusual day" mentioned above. During her interview, Gayle alludes to slowing down to keep the classes together (recall that all five 8th grade classes at her school were using the unit materials), and mentions extending time specifically to work on tables and equations:

> **Gayle**: And also, some of the classes are behind. I say behind but not at the same place because they have students that are struggling a little bit more with the concepts than others. But we didn't want to leave them behind. Say "sorry, we gotta keep going" [laughs]. So, we've kinda slowed it down in places.
>
> **Q**: Give me an example of when you had to slow down.
>
> **Gayle**: When we started using the equations, with the table and process. Some were getting the connections, and some didn't. So we had them in groups, and they paired off, individually and then came back to it. And they've gotten to a point where they've gotten a little bit better. But they still -- they seem afraid of the math - they know the math, but I don't know what is scaring them from it. I think it's just when they hear the word equation they start stressing. So we had to slow down when we started there.

During a different interview, Gayle described leaving the computer lab during a particular activity, and returning to the classroom as a means of fostering understanding in her students:

> **Q**: You talk about needing more time. Can you give me an example where it took more time? …
>
> **Gayle**: We actually had to come back in here [the classroom], because I had a graph that you can pull down, that has the 4 quadrants. We had to

graph it and physically pick it apart. Because they had it in front of them on the computer, and they had it on their book, and for some reason they were not connecting the two. So we come in and have to stop the lessons on the computer and come across the room and pull down the chart and start plotting it, plotting the points, and then discussing it, and showing the process of how to pick it apart, what is the speed once they found the rate, they were just disregarding that, the rate, they didn't know what to do with it once they found it, and how to apply it to the table. So we had to come in and physically re-do it on the graph. I mean, they had already plotted it in their book, they had already seen it on the computer, but for some reason, they need to see it in the classroom, I don't know.

Q: So, they had it in the graph form, and the table form. When you say they didn't make the connection between the two, those are the two you mean, the table and the graph?

Gayle: Right. But I think it was before, when they wouldn't let them have the table, and then they'd look at it, and say 'It doesn't fall pretty,' it didn't fall right on the lines, it would be in between. And so, I'm like, OK, use rate. If you know that at one second it's supposed to be at 4 centimeters, then carry that through, they didn't know how to apply it, like "Oh, we can do that?", and I'm like "Yes, you can use every part that we've been doing." If we don't have the table, we can use the graph, if the graph isn't pretty, we can use the Math. And so, they didn't understand that, so we had to come into the room and work on it on the board.

When Gayle says "they wouldn't let them have the table," she is referring to an activity in which the software did not provide a table corresponding to the motion and graph, but rather instructed students to create the table themselves. The topic came up again later in the interview process. In the quote below, note the reference to using the "distance = rate * time" formula. As we shall see, Gayle refers to this formula repeatedly as she teaches the unit.

Q: So, you were talking about when you had to go back to the classroom. Was that with Roberta [activity on page 13 of workbook, part of *Controlling Characters with Equations*]? That was the first time you couldn't use a table.

Gayle: Right. They didn't have the table, and some of them were like "Well, it doesn't land quite on the line". So, they were trying to round up.

> But you don't always get pretty numbers in Math. So, we went back to the classroom to plot the points.
>
> **Q**: How did you get the points?
>
> **Gayle**: We had the computer lab, I made them use the distance = rate * time. If the rate is such-and-such, where are they supposed to be at one second? At 2 seconds, 3 seconds.

6.5 Class Organization and Level of Directive Teaching

As described previously, Gayle's organization approach to the unit materials was to facilitate student activities through the workbook in a page-by-page fashion. In general, there was an introductory episode for each activity within a lesson (activities most often had several parts and usually corresponded to one page in the workbook). Usually, this introduction was short and left the mathematical work for the students to do independently or in small groups. In the case of the Wendella1 and Wendella3 activities (pp. 24 and 26), Gayle did conduct a quick introductory class discussion agreeing on a prediction for the character's motion before students started work on the activity. Gayle, as will be noted below, believed most students were already familiar with piece-wise motion from class work the previous year using CBR's.

Once again, since both Marilyn and Gayle were observed teaching Lesson 5, this lesson will be described in detail in order to give further insight into issues of classroom organization and levels of directive teaching. The associated analysis includes references to other observation data as well.

6.5.1 Gayle's enactment of Lesson 5

Recall that Lesson 5 is entitled *Wendella's Journey: Moving at Different Speeds* (see Appendix B), and introduces students to multi-segment graphs. (Refer back to 5.3.1 Marilyn's Enactment of Lesson 5 for more detail).

Gayle's lesson plan allocated two days for Lesson 5. For the first day, she had written as her plan:

Wendella's Journey
1 & 2
share stories
talk about what's missing

For the second day, she wrote:

Wendella's Journey
3-5

Lesson 5 contains 5 questions (each question containing sub-questions). It is safe to assume that Gayle intended to have the class work through questions 1&2 the first day, and then questions 3-5 the second day.

Gayle's actual enactment of Lesson 5 extended over portions of three class periods. On the first day, Gayle starts the class period on the final page of Lesson 4, and then moves into Lesson 5 about 25 minutes into the 45-minute class period.

As with Marilyn's description, the following is broken into episodes reflecting class time organization.

6.5.1.1 Introducing episode

The students are grouped with three students around one computer. Gayle instructs the class to open the Wendella1.smw file, but not to run it, just look at it. As

Gayle reads the story aloud, she asks the class questions relating the story to a corresponding graph:

> **T** reads Wendella story.
> **T**: .. slowly, is that important?
> Students: yes
> **T**: OK. How do you know?
> **S**: Because the line won't be as steep
> **T**: OK, the line won't be as steep. She's moving slowly when she's in the swamp. So when she's in the swamp, she's going to go slow. Forward faster when she's on the road -- what kind of line are we going to see with forward faster?
> [student answers quietly]
> **T**: Say again
> **S**: Steeper
> **T**: Steeper. Then she stops and barks for help when she's in quicksand, what going to happen to the line there?
> Students can be heard saying 'stopped' and 'straight'. Several students call out the word 'straight', and gesture horizontally.]
> **T**: Straight? [T gestures first vertically and then horizontally]
> [students are talking over one another]
> **T**: Straight how?
> **S**: Across [gesturing horizontally]
> **T**: [gesturing horizontally] What's that called?
> [students talking over one another. Someone says vertical]
> **T**: Vertical, [T gestures vertically] ...
> **S**: Horizontal.
> **T**: So that line's going to be horizontal. So, you remember some of the stuff we did last year.

Gayle then asks the students how many line segments are on the graph, and how do you know? This is discussed briefly, and the students are then instructed to continue the story, starting with the 2nd line segment. They are instructed to write the story as a group. Gayle tells them "Be specific. What's happening? What cause that line? ... How long was she there?"

<u>Analysis:</u>

As was typical over the three days of observation, Gayle starts class with no review of previous material. Her introduction to the first Wendella exercise is slightly different from Marilyn's. In Marilyn's class, the motion of the Wendella1 graph is explicitly discussed before students write their stories. Here in Gayle's class, the particular graph is not discussed, but students are reminded ahead of time that slowly would imply a not-so-steep line, etc. During her interview, Gayle explains that her students had seen multi-segment graphs the year before (when working with CBRs), so these ideas are not new to them. She also explained that she put the students in groups for this exercise because she thought it would be less stressful that way for any student who didn't remember the movements from the year before.

6.5.1.2 Working on Problem episode

As students are writing their stories, Gayle walks around from group to group. Aloud to the entire class, she makes comments emphasizing that their stories be specific.

> **T**: Can you tell me specifically how long she was in the swamp? How many minutes? .. Talk about it as a group so you agree with what she's doing on each piece of that line segment.

Gayle once again emphasizes including elapsed time in the story, but suggests other details as well, asking for example:

> **T**: How long does she slow down? How do you know?
> **T**: Did you tell me why she slowed down? And where she slowed down?

As students continue to work, Gayle instructs them to run the simulation after they complete the story. Students run the simulation and laugh at the dog's movement. Gayle asks: "Did the dog stop?", and students answer "yes."

6.5.1.3 Follow-up episode

Gayle then calls the class together and asks group #2 to read their story. One member of the group reads the story:

> **S**: Wendella started out fast on the road. She was happy to be on her journey. Then she slowed down at the swamp for 6 minutes. She got stuck in a quicksand for 2 minutes. Then she [pause] then she ran back to get home and it took her 1 minute.
> **T**: So was she traveling pretty fast?
> **Ss**: yeah.
> **T**: Were they kinda specific?
> [students quietly answer]
> **T**: Did she tell us how long she was, uh, stuck in the swamp?
> **Ss** [quietly]: yes.
> **T**: Did she tell us how long they were stuck in the quicksand?
> **Ss** [quietly]: yes.
> T: Yes. So I thought that was pretty good.

Another group is then called upon to read their story. Gayle speaks over the beginning to get the attention of the other students. The reader continues:

> **S**: She was happy to be on her journey. Then she was walking slowly in the swamp for 6 minutes. She got stuck in a quicksand for 2 minutes, and [pause] she got out and she took her <inaudible>
> **T**: One minute to what?
> **S**: Took her a minute to get <inaudible>
> **T**: OK.

Gayle then immediately calls upon the remaining group to read:

> **S**: Wendella started out fast on the road. She was happy to be on her journey. Then she got tired and slowed down for 6 minutes because she <inaudible> the swamp. She then tripped and fell over a <inaudible> and lay there for <inaudible> minute. Then she quickly ran home because it was curtain time in one minute.
> **T** [laughing slightly]: OK. It was curtain time in one minute so she hustled it home. OK. So that's pretty good. Most of you, you told me how much time it took her, but did any of the groups [pause] -- shiny faces on me -- did any of the groups talk about what distance was covered per line segment?
> [Ss answer quietly]
> **T**: Could you have added that in?
> **Ss**: Yes.
> **T**: Yeah. So we could add a lot more specifics while we're doing that.

Analysis:

This enactment corresponds to Gayle's lesson plan. Students have shared stories, with a subsequent discussion on the specifics and “what's missing” from the story (distance is missing). As will be seen, this focus appears to come from her training experience. Although the first story says the dog “ran back home” and the last story speaks of running home at the end also, there is no discussion of where the dog started the journey (from the graph, if the dog started from home, she did not end at home). Gayle seems to be strictly focused on the specification of particular story details. She focuses on these details in her after-class interview as well, when asked about the intentions of the lesson:

> **Q**: Do you think the lesson went the way it was intended?
>
> **Gayle**: I think it did. Now, I did do some directing on Wendella from the beginning, asking about the time, how much time was she on the road? And they were able to clue in on that. Then I didn’t clue them in on the distance, to see if anybody would get that on their own. But, they didn’t, but their stories will get better as they go, now knowing what I’m looking for.

6.5.1.4 Introducing episode

Gayle then spends less than half a minute introducing the first part of the next problem to the class. She tells them to look at problem #2, and reads the instructions from the workbook aloud: “Mark on the graph below, show when Wendella was in the swamp, in the quicksand, and on the road. Mark the times on the minute axis. She adds: “OK, so label those line segments.”

6.5.1.5 Working on Problem episode

Gayle works with one group of students:

> **T**: Did you all mark the times on the minute axis? Not yet. [T takes her thumb and draws an imaginary line on the graph of one workbook, from the end of the first line segment down to the x-axis]. How long was she from there to there.
> [A student starts drawing vertical lines on the graph at each endpoint, down to the x-axis, and writing in the times for each leg of the journey].

Gayle says aloud to the entire class to remember to write down how long the character was on the road, swamp, quicksand, etc. She then goes to another group and talks briefly.

Gayle then tells the class to continue on with the other two parts of the question. As the students continue working, Gayle goes over the answers with the students, for instance:

> **T to class**: For the third line segment, when she was in the swamp: How long was she in the swamp?
> Students answer: 4 minutes.
> **T**: Does everyone get 4 minutes for the swamp? Ooh,<student> is doing a table. Looks good.

One of the students, Celia calls Gayle over and makes an observation, which Gayle shares with the class:

> **T**: Celia noticed that she was in the swamp the same time, but the roads were different.

Later, Gayle asks how long Wendella was on the road the second time. A student says 4 minutes, then says 6 minutes. Gayle says “What?” with a questioning tone. Student says “I’m confused” and Gayle goes over to this student:

> **T**: Show me the road.
> **S** points to first road segment. T says no, we got that one.
>
> [A bell rings to indicate the end of class, and Gayle excuses most of the class. She continues to work with the confused student]:
>
> Gayle says “Did it go 1,2,3,4,5,6?” They agree that’s not right.
> **T**: So how many minutes did it take to <inaudible> ?

[Student answers, inaudible. Sounds like she is counting]
T: So mark it here.
T draws vertical lines down from the start and end point of the segment, down to the x-axis, and says "Here's where it starts. Here's where it ends.
S: Oh, two. [The vertical lines show a 2-minute segment].
T: Alright.

This is the end of the first day Gayle's class worked on Lesson 5.

Analysis:

Although Gayle shares Celia's observation with the class, this is done with little detail, and no common visual to point out exactly what Celia was noticing. It is also important to point out that Gayle often helped students to determine the time or distance of a leg of the journey. The interchange above with the student who said "I'm confused" is typical.

6.5.1.6 Follow-up episode

(This is considered a follow-up episode because students had already begun this work the day before).

At the beginning of class the following day, Gayle gives each student a sheet of paper with a table on it, for them to fill in to finish Part b of page 25. The page had the following information printed on it:

Wendella

SEGMENT	MINUTES	METERS	SPEED D=R*T
1st			
2nd			
3rd			
4th			
5th			

6.5.1.7 Working on Problem episode

While students work, Gayle walks from group to group, asking students about time and distance and the associated rate. She emphasizes that the students label their numbers appropriately (minutes, meters, meters/min).

Just as Gayle helped students determine time calculations the day before, she helps some students individually today with calculations for distance and speed. In the following example, she helps a student determine the distance traveled in the third leg of Wendella's journey in activity #2:

> **T**: So, the 3rd line segment. How much time was spent there? [T counts off 1,2,3,4 pointing to the 3rd segment as she does so. This time info is already written in the student workbook.] And what was the distance traveled?
> [Students are talking, but it is inaudible.]
> **T**: Did she start at the origin? Ah, but you're not thinking, it's trying to get you to think. You're telling me numbers starting from the origin, and I know that line segment didn't start -- do you have an eraser?
> [student drops pencil/eraser, makes a comment, T laughs]
> **T**: It started where? OK, at 300 and where did it end?
> **S**: at 400.
> **T**: OK, so what was the distance traveled?
> **S**: <inaudible>
> **T**: 100 meters. So, go back and fix the other stuff you have on your chart.

As students complete part B, Gayle tells them to continue on to part C.

Gayle continues to walk around the room. In most cases, the teacher-student interactions are short. In many cases Gayle's input is to clarify the problem statement, but sometimes she helps students with calculations, as in the following example.

> **T to student** on the left, pointing into his workbook: Here's the line segment, and here's the distance, and now you need the speed.
> [Student on left speaks, referring to his workbook]: I'm trying to <inaudible>
> **T** [pointing into his workbook]: R times, how much time was it for that one?
> **S**: <inaudible>

T: So that t should be replaced by <inaudible>. So therefore r is equal to
S: 300
T: Hm-hmm. 300 what? [pause] We're talking about rate. Speed.
[pause]
T: What's my unit measure for the distance?
S: <inaudible>
[T points to workbook]: per what?
S: minute
T: Yes.

Analysis:

This above example is typical of how Gayle helps with a calculation. Speed is always calculated using the formula d = r * t; the current distance and time are plugged into the formula and then r is determined. "Rate" and "speed" are used interchangeably; Gayle often uses both at the same time, as in the example above.

This example is especially interesting because the students' computer screen displays a copy of the graph for this activity, but the SimCalc unit did not provide this graph as a file – one or both of these students took the time to create the graph themselves, although it is not referred to during this interchange. This implies the students had sufficient independent time to play with the software and make it their own. During the three days of observation, Joel, the student on the right (who remains quiet and plays with his fingers during the interchange) is repeatedly observed and videotaped referencing and using the software dynamically. This is not true of the rest of the class; in most cases, both teachers and students refer to the workbook rather than the software.

6.5.1.8 Follow-up episode

After 17 minutes of class time, Gayle conducts a whole-class follow-up discussion on activity #2, in which she goes over all the answers to the questions. She begins by getting the student's attention:

T to class: Alright. Let's go ahead and talk about this. Oh, man, I like this. You are going and plugging and chugging. Shiny little faces all on me.
...
T: Now, when you started, first of all, everybody's maps should be the same, because do we all have the same graph?
Ss: yes.
T: Yes. So, for the first line segment, what was the time spent there, Amy?
Amy: One minute?
T: One minute. And what was the distance traveled on that one, Tina?
Tina: 300
T: 300 meters. And for the speed, what was the speed there, Ed?
Ed: 300
T: 300 what?
Ed: [pause] meters per minute.
T: meters per minute.
Ed: [pause] meters per minute.
T: meters per minute. So, that one was pretty straight-forward, because where did it start?
S: At zero.
T: It started at the origin. It started at zero. So, when we go to the 2nd one, how many minutes was it in the second line segment?
S: <inaudible>
T: Two. And then what was the, how do we get that flat line? [T gestures, making a horizontal line with her arm]
S: Because it didn't move.
T: It didn't move. So, what was the distance traveled in that time?
Ss: Zero
T: Zero. If you're standing still, you're at zero. And then, so therefore, what was the rate during that time?
S: Zero.
T: Zero. Because you weren't moving. Rate is speed, if you're standing still, you have none. Third line segment, Celia. How long's the time there?
[Celia answers]
T: Four minutes.
T: And how many meters did I travel there?
[Student answers]
T: A hundred. It started at 300 [gesturing with her hand], I ended at 400 [gesturing with her other hand, as if the 2 hands were the 2 endpoints]. What was the distance traveled [gesturing, as if making a line between those 2 points]. Only 100. Some of you were putting the 400 there. Therefore, when you do your distance = rate * time, Celia, what was the speed?
Celia: <inaudible>

T: 25 meters per minute. And the 4th, how many minutes did we spend there?
S: <inaudible>
T: Uh,huh. Two minutes. And what was the distance traveled there?
S: <inaudible>
T: 600 meters. Where does that start?
S: <inaudible>
T: And where does it end?
S [looks at workbook, turns to teacher]: 1000.
T: The distance between that was your 600. What was the speed there? [Calls on specific student]
S: <inaudible>
T: 300 meters per minute. Don't forget your labels. Those are important. The 5th line segment, Joel? How many minutes was I there?
Joel seems to be saying something, then says '4 minutes'.
T: 4 minutes. And, what was the distance traveled there, [calls on a student]?
S: 100 meters
T: 100 meters. What was the speed there? [calls on a student]
S: 25 meters per minute.
T: 25 meters per minute. That was pretty easy. If you paid attention to your starting points. Remember, we don't always start at zero, just like when you get a head start. You have to take that into account. Part C should be in your own words.

<u>Analysis:</u>

Gayle's follow-up has a few interesting aspects. Note again that only one mode of solution is considered to determine speed (using the formula distance = rate * time), and that there is no common visual to refer to. Still, Gayle does provide a follow-up, making sure students are aware of the correct answers and at least one way to find them. Although she uses gesture rather than an actual graph in her explanation, she does point out that the starting point of the segment is important in determining the distance traveled. She also calls on specific students, encouraging all students to be engaged and verifying that all students have been on task during the small group work. This is in contrast to Marilyn, who asked questions to the entire class, perhaps allowing some students to dominate and others to passively copy down the answers.

6.5.1.9 Introducing episode

Gayle instructs the students to turn to the next page (page 26) and to open the file Wendella3.smw. Before allowing them to "press play", she mentions that one of the students had already noticed something about the graph.

> **T**: <student> already made an observation before she even played that. As soon as she saw the screen, she noticed something. Anybody else notice something about that graph?
> [Many students call out. One or more talk about Wendella going backwards.]
> **T**: How do you know she went backwards?
> [Many students call out.]
> **T**: Because the line goes back down. [T gestures with her arm, negative sloping line]. So, I'm so proud of you all for remembering that So, go ahead and press play. It says [T pauses, walks around a bit]. Notice the different rates. Notice the change in direction. And then the change in rate again.

Students run the simulation. There is laughter and noise. One student calls out "Oh that is so cool." Noise and laughter continues. Students seem to be talking about the simulation. The introduction continues, with Gayle reading the instructions for part A of the activity:

> Run the file. Wendella does something new here! Write a story to go with Wendella's journey.

They discuss Wendella's possible motions (slow in the swamp, fast on the road, etc.). One student asks if she can write about something other than a swamp, Gayle says that's OK. Gayle then continues with more instructions:

> **T**: Here's what I want you to keep in mind when you write this story. I want you to keep in mind how much time she spent in each line segment.
> **S**: Put that in the story?
> **T**: I would like that. Because we want to improve our stories from last time. And I also want you to include the distance traveled for each line segment. OK? So, it's going to take some thought for this one. I want you to be a little bit more precise in wording. You can do this as individuals or as a group.

> [a few seconds pause before T speaks again]
> **T**: How much time for each line segment, distance for each line segment … When you're finished your story, you can go ahead and work on B, C, and D, because all that pertains to that one graph.

<u>Analysis:</u>

Notice the laughter in this episode. Another study within the Scaling Up SimCalc project focuses on classroom laughter, finding variation across classrooms in terms of both amount and type (McLeese & Tatar, 2009). The study is investigating the relationship between laughter and performance; preliminary results indicate a most positive connection when the laughter is integrated with the mathematics and is associated with positive challenge.

As with the first simulation in the lesson, Gayle has discussed the graph-motion connections with the class before giving them a chance to predict the outcome individually. Many of the students call out the answer, so most of the class did seem to already know that a downwards sloping line indicates backwards motion. It seems that from Gayle's point of view, this is simply a review from last year. But since the students had seen the concept before, they might have benefited from a deeper discussion, for instance discussing <u>why</u> the line slopes back down. This was a topic in the other classes observed enacting either Lesson 5 or Lesson 6 (Carly conducted a discussion on this topic, Marilyn and Sharon both asked the question why and commented briefly). However, it appears Gayle didn't consider this as an issue to discuss. From her interview:

> **Q**: What big Math ideas came out of today's session?
>
> **Gayle**: Main one was just that they know what the line is doing if it drops back down, what is that doing for the motion of the character, and it's actually turning back in the opposite direction it was traveling. So I think that was the biggest that was supposed to be focused on for the day.

Q: So how do you see their use of the software affecting their learning?

Gayle: For today, I think it was just kind of a fun day for them, because if they already remembered what was causing that line to go back, it wasn't as much exploration and learning it, it was just they knew what it was, so they could just play with it. They knew what they were doing. I think they felt confident. It boosted their confidence level knowing that they knew something before they even started.

Note that Gayle has focused the students on the time and distance calculations when writing their stories. As we will see, this was also a focus in her training.

Also, although Gayle's introductory episodes did not provide workbook answers (as Marilyn did), Gayle often directed student's focus, as in this case, perhaps influencing how they approached the unit activities.

6.5.1.10 Working on Problem episode

As usual, Gayle walks around the room as the students work. She is often quiet as she looks over students' shoulders, but the following examples are typical interactions with the students:

T [reading part B, p. 26 aloud to student]: What did Wendella do 6 minutes after starting this journey?
[Gayle points to student's workbook]
Student: Going back in time
[**T** pushes student lightly and playfully]
Gayle: No, not going back in time. Did she go to the negative side?
Student: No.
T: She just changed direction. So, how did this graph show this motion? Do you know which part of the graph she went back?
Student: Where it goes down [Student gestures downward with his hand]
Gayle: OK. That's what it wants to know.
[**T** starts to move on, but returns, pointing to student's workbook]
T: Be sure you say the line goes down, so we know what you're talking about.

Gayle works with another student:

> **T**: (reading) “What did Wendella do 6 minutes after starting this journey?” So, where’s 6 minutes on your graph? Student points [in workbook]. T: OK. So go up there. [pointing in workbook]
> **S**: She turned back?
> **T**: Ah. OK, that’s what it wants to know.

Gayle works with another student:

> **T**: What’dya got?
> **S**: I don’t know, it says between 6 and 8 and <inaudible> seven?
> **T**: No, <inaudible>. Which line segment are we interested in?
> [S points to the graph in his workbook]
> **T**: So, what line segment is between 6 and 8?
> **S**: [pointing at the graph with 2 fingers, but not between 6 and 8 minutes]: Seven
> **T**: You’re not listening to the question. Line segment. The numbers off your line segment.
> **S**: [counting along x axis, starting at 1]: one, two ...
> **T**: What are line segments?
> **S**: I don’t know. I forgot.
> [T turns the page back to the previous pages (24-25). T points to the line segments in the graph of 2A]
> **T**: Aren’t these line segments?
> **S**: Yeah.

The discussion of “line segments” continues, and the student finds the segment between 6 and 8 minutes, and determines the distance traveled. Gayle then helps him determine the elapsed time:

> **T**: How many minutes are there between 6 and 8?
> **S** : [points from 6 to 7 to 8 on the x-axis]: Three? Or, between them?
> **T**: Um-mmm. Can you start where you’re standing? Turn around and look at me.
> [Student turns to look].
> **T**: Do I start counting where I’m standing? One, two, three? When do I start counting?
> **S**:<inaudible>
> **T**: Which step? [gestures to her ear]
> **S**: First step. [More than one student answers.]
> **T**: First step. First step out. So you do not count where you’re standing. You start at 6 minutes, but you’re standing at 6 minutes. If you stepped out, that would be [pointing to the 7 on x-axis]
> **S**: one
> **T**: And from here to here would be [pointing at 8]

S: Two
T: Two minutes. Make sure you use your formula.
S: [*off-camera. This sounds like a different student*]: So, 2 into 700.

The 700 is not correct, but it is unclear which student says this. Gayle moves on to help a nearby student:

[T moves towards student's workbook, and says she has a problem with what the student is doing. This is the student who has been paying attention to the last interchange, and perhaps said 2 into 700.]
T: Where did it start? [Teacher and student are looking at the workbook]
S: <inaudible>
T: Where did it end?
S: <inaudible>
T: So what was the distance traveled from here to here? [pointing in workbook]
S: Seven, wait, that would be <inaudible>
T: Let me see your pencil. [T is writing in the student's workbook] Label it. Here's 700, here's 100. Do you count where you're starting and where you're ending?
S: No. It's 600.
[T makes agreeable noise.]
S: So it's 600 over 2?
T: uh-huh. Make sure you put your unit of measure for your rate.

Analysis:

It is interesting to note that the idea of "time going backwards" came up in Marilyn's class as well. As with Marilyn, the software is not used to explore this misunderstanding. Rather, Gayle provides the correct answer for the student ("she just changed direction"). It is not really clear what Gayle meant when she asked "Did she go to the negative side?"

It is important to note that in almost all circumstances, Gayle's focus is on the workbook, not the technology resource. Most students also primarily refer to the workbook (although as noted earlier, one particular student out of the nine (Joel) invariably referred to the graph on the computer screen rather than the workbook, and the camera often captured him using the simulation capabilities). Gayle never suggests using the software to help clear up any difficulties. Her approach is, in general, procedurally mathematical and abstract. She often referred to the “line segments” of the graph, perhaps trying to emphasize the mathematics but failing to emphasize that these line segments represent portions of the character's journey.

It is equally important, however, to note that Gayle is still helping the students develop the basic tools to understand and work with piece-wise linear graphs. In all the individual exchanges above, the students seem to be engaged with the process. Gayle focuses the students on particular solution methods, but she does not give out answers; students work out the solutions themselves. Gayle seems unaware of the power of the software, which might have been a helpful tool in many of the above exchanges. One might say she is adequately teaching the topics through the curriculum materials, but that learning to more effectively incorporate the software would likely improve her implementation.

6.5.1.11 Follow-up episode

As a follow-up, Gayle has several students read their stories aloud to the class. Before beginning, Gayle instructs the class to be listening for specific details:

> **T**: OK. Here’s what I want you listening for. Does her story match that graph? Does it match each line segment on that graph? Does she mention how much time she spent at each particular point? Does she mention the distance that she traveled at each particular point? OK.

The first student reads her story:

> (story #1):
> **S**: Wendella was taking a little walk. It took her 4 minutes. She <inaudible> to chase a squirrel, it took her 2 minutes. She turned around because she forgot her little puppy, which took her 2 minutes. Finally she walked again and it took her 4 minutes.

As this student reads, the rest of the class is attentive. They are looking at the student, rather than at a computer screen or the graph in the workbook. They continue to look at either this student, or at Gayle, during the subsequent discussion:

T: OK. What was missing?
Ss: Distance
T: The distance was missing, but what else was missing?
S: She went back.
T: Did she tell us how we were traveling?
[pause]
T: Now if you're chasing then I guess you're chasing kinda --
S: fast
T: <inaudible>
S: Well, if you're chasing a squirrel, you're going fast
T: Yeah. Unless you're an old person, how fast can an old person travel? And if you have a hurt back? OK, so don't forget, you've got to tell me, how you were traveling.

(story #2):
S: Wendella walked 100 meters to the stop sign in 4 minutes. She ran 6 meters across the street in two minutes. She goes back 600 meters to the stop sign to get her housekey that she dropped in 2 minutes. Then she, then she sees that she has, that there's no cars in the road, and she walks 100 meters in 4 minutes to <inaudible>.

T: Good. So she included the kind of motion that Wendella was doing, she included how much time it took her, and the distance that she traveled. Good. Go ahead, <student name>.

(story #3):
S: Wendella went slowly through the mud 100 meters. Once out of the mud, Wendella sped down the road for 500 meters in 2 minutes. When she got to the stopsign, she forgot that her puppy wasn't as fast as she was, so she had to go back the 500 meters and that took two more minutes. Back at the woods Wendella trudged through the mud 100 meters to get back to her puppy.

T: Good. OK, last victim or volunteer. <student name>

(story #4):
S: Wendella walked 100 meters through the swamp. When she got to 100 meters, she remembered she did not sprint her 600 meters for her morning workout. It took her 2 minutes. Then she remembered her date was going to be at her house in 2 minutes. So she sprinted another 600 meters

> and got stuck in the swamp, that was 100 meters long, so it took her another 4 minutes to get home.
>
> **T**: Pretty good. I like that story. Running back to the boyfriend.

<u>Analysis:</u>

Gayle seems to be focusing on a formulaic approach to the exercise. While chasing a squirrel might be considered a reasonable verbal representation of a steep line, it is important to Gayle that students explicitly specify whether the dog is running or walking.

Although Gayle had told the students to check if the stories matched the corresponding graph, the graph is not referenced at any time during the sharing of these stories. The video does not capture any student looking at the computer screen. Some students look down occasionally and might be looking at the graph in his/her workbook, but there is no clear indication of this. Gayle appears to focus on whether or not the stories included the type of motion and the time and distance calculations, to the exclusion of any other details. None of the stories explicitly point out that the Wendella character turns around and goes forward again during the last leg of her journey (although it is implied in story #2). In fact, the last two stories imply that she keeps moving backwards (towards her puppy in story #3, or towards home in story #4). There also appear to be numeric mistakes in stories #2 and #3, although student voices are not perfectly clear on the video and therefore the transcription is possibly incorrect. It is also interesting to note that the stories specify the type of motion in every leg of the journey <u>except the leg where the character goes backwards</u>. Only story #4 indicates Wendella is running (sprinting) at that time. It is entirely possible that the students are unsure of the type of motion in this case. This issue came up in both Carly's and Marilyn's classes during this activity, but is not a topic of discussion here.

6.5.1.12 Introducing episode

Gayle then instructs students to start problem # 4 (page 27). She asks “So, now you’re going to do your own graph. Is there any stipulations for that graph?” With a brief discussion they conclude that students need to create a graph that will make the character move forward and back at least two times. This time, Gayle instructs each student to use their own computer.

Analysis:

It is important to note that Gayle is varying how the students work over the course of the lesson. First they worked in groups, then they were allowed to choose between group and individual work, and now they are instructed to work individually. This slow transition to individual work might be advantageous. Gayle noted in her interview that the experience of this intervention helped her see the value of group work:

> **Q**: Has this unit affected the way you teach?
>
> **Gayle**: I think it has in some ways. I know in the classroom we do a lot of individual work the majority of the time. And, in here, seeing them to work together, they’re eager to help each other. When one of them truly understands, they’re really good about saying “here’s what it’s doing. Let me help you.” My biggest thing in the classroom has been that they’re just going to tell them what to do and not explain how to do. So, I kinda stay away from group activities, because I wonder if they’re really helping each other or setting each other back because they’re saying “Here, write this”. In here, I think I’ve been able to see how beneficial it is to have them work in pairs, work in small groups. They truly do help each other. I have caught some that just say “Here, copy this from mine,” and I say “No, no. You need to understand. You can help, not hinder.” I think I’ve learned that you have to give them the benefit of the doubt, so they can grow.

> **Q**: Do you think this experience will affect the way you teach other curriculum?
>
> **Gayle**: Possibly. I think I'll make sure I kind of go back and forth from just not being teacher-lecturer. We have a lot of teacher-lecturer, but we have a lot of class discussion. And I think it would be helpful if I included group discussions, within groups and then come back as a whole, because I think that's kind of something I got to do in here that I think would probably be beneficial also in the classroom.

6.5.1.13 Working on Problem episode

While students are working on the activity #4, camera shows (from a distance) many student screens. They all have appropriate graphs that would indicate motions forward and backward at least twice. Gayle has this interaction with one student:

> **S** [showing teacher graph on screen]: Is this what they're asking?
> **T**: OK, so put that on here [referring to workbook].
> Student runs the simulation, and laughs.
> **T**: Alright. Now do your sketch, and you get to write a story on yours.

Gayle looks on as another student is manipulating her graph, moving it up and down. Gayle says "Put it where you had it before". Student moves it down again, which results in certain portions of the graph being below the x-axis. Student runs the simulation.

Class ends on Day 2 with the students working on activity #4. They are told to finish the activity as homework.

<u>Analysis:</u>

It appears that Gayle simply looks at the first student's static screen and tells him to sketch it in his workbook ("so put that on there"). She doesn't encourage him to run the simulation, but the student does so anyway. They don't verify that the dog does as he is supposed to, but since the graph is correct, it is unclear what might have happened otherwise. During the three days of observation, Gayle never encouraged the use of the software as a tool to test and possibly revise student work. Her approach seemed to be to check the student's work and help him/her (by hand) if incorrect. If the work was correct, she might then suggest the student check it with the software. This approach may have limited student’s use of the technology resource.

With the second student, there is no discussion about what happens. Still, Gayle was encouraging the student to explore this setup, with portions of the graph below the x-axis. Although Gayle does not explicitly tell the student to run the simulation, the student does so anyway. It appears that Gayle does recognize the software as an exploration tool, but perhaps doesn't see its effectiveness as a tool for iterative feedback.

Not all teachers allowed the workbooks to go home. Marilyn, in particular, chose not to, because the workbooks needed to be returned to the project as data, and she feared some students would lose them. Assigning homework may have made it possible for Gayle's class to complete more of the workbook activities.

6.5.1.14 Follow-up episode

(Begin Day 3)

During the Day 2 after-class interview, Gayle was asked about a particular story from activity #3, which did not seem to accurately describe Wendella's motion. At the beginning of Day 3, Gayle told the class that she had missed something yesterday, and handled the discrepancy in the following manner:

> **T**: So, Celia, can you do me a favor, and re-read your story from yesterday?
>
> **Celia**: Wendella walked 4 minutes through the swamp. When she got to 100 meters, she remembered she did not sprint her 600 meters for her morning workout. It took her 2 minutes. Then she remembered her date was going to be at her house in 2 minutes. [Student makes a mistake in reading and repeats a portion of the story.] So she sprinted another 600

meters and got stuck in the swamp, that was 100 meters long, so it took her another 4 minutes to get home.

T [speaking directly to Celia, not to class]: So here's what I didn't catch. That you didn't turn direction here. I heard when you turned back home for the date, and then you never mention what caused this to start going back this way [T is pointing in the student's workbook to the last piece of the function of Wendella3.] Were you still going back home when you went this way.

Celia murmurs.

T: You turn direction. I didn't catch that yesterday. OK? So, be careful. And Thank-you.

Gayle then has two students share their stories from activity #4:

Joel: She ran 100 meters, but she ran back home because her husband had a heart attack. But he was faking. She ran another 100 meters, her husband called, but he was faking <inaudible>. Then she went 200 meters.

T: OK. I got the motion where she was going somewhere and she came back because of a heart attack. Then you said she ran another 100 meters. What direction did she run the 100 meters? [pause]. Was she still running towards home? Which way was she going? Which direction?

Joel: Up the street, I don't know.

T: OK, that's what I'm saying. You were telling me the distances she traveled, but you forgot to tell me the direction that was generated by your graph.

[At this time, Joel opens up the SimCalc software.]

T [pointing very briefly to student's workbook as she is speaking]. OK? [T walks away].

Celia reads her story as well:

Celia: Wendella was running through the forest. She noticed she forgot her bone so she has to run back. The she starts going forward, when she runs into a bobcat and she starts to go back. Then she <inaudible>.

> **T**: OK. So you told me which direction until the very end. She chases a cat through the woods. Was she chasing the cat in the opposite direction, or does she turn?
>
> [Camera shows Celia's graph as both she and T are speaking. It is not clear whether T is looking at the graph or not, but it is clear that Celia is looking at the graph.]
>
> **Celia**: Forward. [Celia's pencil is on the last segment of her graph as she says this. She then adds to her story].
>
> **T**: OK, that gets it.

The class goes over part D as well, agreeing that a line segment must slope down to make the character go backwards.

Analysis:

Celia's murmur after Gayle asks "Were you still going back home when you went this way" appeared to be an "I don't know" kind of sound. It is not clear whether this interchange cleared up any misunderstanding that may have existed.

It is interesting that Joel decided to open up SimCalc during his interchange with Gayle. This might be a coincidence, or perhaps he planned to figure out the direction using the software. As previously noted, Joel was observed using the technology resource more than the others.

Although Celia's activity #3 story had been incorrect (see first vignette in this section), and Gayle's intervention possibly unclear to her, during the discussion of activity #4 she has no trouble recognizing that the last leg of this journey is in the forward direction. Perhaps activity #4 helped clear up any misunderstanding that might have existed.

Since activity #4 had each student making a unique graph, the students listening clearly had no opportunity to connect these stories to their corresponding graphs. It is not even clear that Gayle is checking the stories for accuracy, although it is possible she inspected them while the students were working.

6.5.1.15 Introducing episode

Gayle then tells students to look at the final page of the lesson. She reads the instructions aloud, and tells them they have 5 minutes to do the work.

6.5.1.16 Working on Problem episode

Students work quietly and individually at their own computers. Gayle walks around looking over shoulders, but stays uninvolved for a while, then answers a few student's questions quickly. She asks one student to explain part of her graph.

The student screens show they have created multi-segment graphs with negative, positive, and zero-slope segments.

6.5.1.17 Follow-up episode

Gayle has a student read his story for activity #5. As before, there is no reference to the graph before, during, or after the story is read. After the student reads, Gayle ends Lesson 5 with this comment:

> **T**: OK. Here’s what I’ve noticed with some of your stories. You’re telling me, you’re including the distance traveled, and sometimes you’re telling me how long it took to travel there, but are you telling me anything about the speed? The rate at which your character is traveling? So that way the reader knows whether the line is going to be steep or somewhat shallow. So, be leery of that. That, when you’re telling a story, you want to be able to be as specific as possible. If we asked somebody to sketch your story, without giving them a visual, they would be able to say ‘Well, they’re traveling fast, if their rate is fast, it’s going to be a steeper line, so

> you kinda need to include stuff like that in your stories, so we know how to draw our line segments, and piece that journey.

It is now about 15 minutes into class, and Gayle starts Lesson 6.

<u>Analysis:</u>

Focusing students on being “as specific as possible” seemed to be the crux of Gayle’s approach to the story activities of Lesson 5. From her comments above, one might wonder what Gayle understands about how much information is required to reproduce a graph. One might also wonder about her understanding, based on the following excerpt from her interview:

> **Q**: OK. Back to Wendella, just for a second, I noticed at the end, you were telling them things to add, things that would be good to add to their story, and things like that. Do you have any connection between what you were stressing, and the workshop? Do you remember the workshop at all? Or is it just -
>
> **Gayle**: No, just some of the things that I noticed as they were reading it, and as I walked over them and watched what they were writing, they were, I had mentioned, I said, include the distance and the time, which probably now I feel that I shouldn’t have, because I think they were more focused on that, versus what direction was the character actually traveling. They didn’t mention how fast or how slow, there can be, their fast might not be somebody else’s fast. So, I think maybe we might do some stuff in class, to where they can actually, sketch a graph, and then write a story, and then swap, just the stories, to see if we can generate the same kind of graph, based on the kind of story that they wrote. And then, maybe they can see, well, maybe I need to be more specific, because the graphs will look different. They can be interpreted in different ways by different people.

Certainly, speed would not be essential to reproduce a graph if time and distance of a journey were both already specified, as Gayle had encouraged her students to do. Teacher and students may have come to that conclusion together had they tried to follow a story along with the graph, but none of these follow-up episodes included any explicit reference to the graphs or simulations corresponding to the stories, not even for activities in which students invented their own individual graphs. Although Gayle talks about having students swap stories and generate graphs at a later time, there is no evidence that she ever actually did so, and the class had already moved into the next lesson at the time of this interview.

There was no projection device in the classroom, but Gayle mentioned in an earlier interview that she typically called students to one computer for class discussions "where I could run the simulation and point some stuff out to them." It is not clear why this did not occur at all during the three days of observation.

It is also important to point out that there were additional observed instances in both lesson 4 and lesson 6 material in which Gayle directed students to approach the activities in a certain manner, even though multiple solutions methods were in fact possible. These directions usually privileged algebraic formulas (for instance, and most often, distance = rate x time) over a more graphical or motion-related approach to the activity, which again resulted in minimal interaction with the software. It is not at all obvious that this avoidance was intended, but might have been simply a result of Gayle's personal understanding of the mathematical material, or her perceptions about what would be important for students on tests or in subsequent material.

6.6 Comparison with Other Case-Study Teachers

6.6.1 Time and Materials

Having established that Gayle's M1 gain score was exceptional and her M2 gain score below treatment average, it makes sense to look more closely at the teacher daily logs. ***Table* 24** below compares how the case-study teachers divided up class time between the early lessons and lesson 10, which focused on M_1 skills to some degree, and the later lessons (5-9) which focused on M_2 skills in many ways. Recalling that Gayle's superior gain scores over Sharon's and Carly's was especially surprising (as detailed earlier), it is interesting to first compare Gayle to these two teachers in particular. These three are listed first and boldfaced for easy reference. First, it is clear Gayle spent more days on the M1 lessons than the M2 lessons, while Sharon and Carly spent about the same time on each. In terms of overall time, Carly and Sharon spent less time than Gayle in the M1 lessons, and more time than Gayle on the M2 lessons of the unit. These differences seem to be somewhat reflected in their M1 and M2 gains.

Table 24:Time spent, divided into M1- and M2- focused lessons

Teacher	Region	Days on Lessons 1-4 & 10	Days on Lessons 5-9	Minutes per day	Minutes on Lessons 1-4,10	Minutes on Lessons 5-9	M1 gain score	M2 gain score
Gayle	**B**	**10.5+**	**5.5**	**45**	**472+**	**248**	**4.1**	**3.7**
Sharon	**B**	**6**	**6+**	**55**	**330**	**330+**	**0.9**	**4.3**
Carly	**C**	**5-**	**5-**	**80**	****420-**	**400-**	**2.5**	**5.0**
Kate	A	3+	3	75	225+	225	1.1	4.1
Marilyn	A	7-	3	45	315-	135	-0.1	2.3
Wendy	A	17	8	50	850	400	1.9	2.8
Jackie	C	7	6	63	441	378	1.6	4.9
Samuel	C	7	6	63	441	378	2.2	4.2
Treatment average							2.0	4.5
Treatment stdev							1.4	1.9
Control average							1.6	1.2

**recall Carly specified 20 minutes on her 11th day (lesson 10). 20 min added to her total

The differential in time between Gayle and Carly for lessons 1-4&10 cannot entirely account for such a discrepancy in M1 gain scores, but it may be one piece of the puzzle. It is interesting to note that Sharon, Kate, and Marilyn spent much less time on the M1 lessons than the other teachers and had the lowest M1 gains, more than ½ a standard deviation below the treatment average (Marilyn considerably more). In contrast, Wendy's class of low-achieving students, who were given an extraordinary amount of time on these lessons, had M1 gains very close to treatment average and above the control average.

As for M2 gains, Marilyn's time on these lessons is comparatively quite low, as is her M2 gain scores. Wendy's time is comparable to the other case-study teachers with lower gains, but note that her low-achieving class was given twice as much time as the others in the early lessons to achieve comparable M1 gains. Kate, with a high-achieving Algebra I class, spent less time than Gayle but had somewhat higher gains, while the rest of the case-study teachers spent more time and had higher gains than Gayle.

Lesson 10 is an interesting point to consider. Kate, Marilyn, Jackie and Samuel never got to lesson 10, which covered proportional versus non-proportional linear relationships, considered an M1 topic. Carly specified in her log that she spent only 20 minutes on this lesson, apologizing and saying she preferred to teach it her usual way the following week (after the SimCalc post-test). From her log:

> We didn't really cover this the way I should have! So it was intended to be taught, I'm sure. I thought it was too big a jump into prop. v. non-prop. And since it's such a major focus tek in 5th [sic] grade, I prefered to wait & teach this in depth next week. Sorry!

For further insight, it is once again interesting to compare Gayle to Sharon and Carly in particular, specifically concerning lessons 3 and 4, which focused on the important M1 skill of representational translations. Sharon spent two (55 minute) periods on lessons 3 and 4 together, while Gayle spent more than four 45-minute periods, roughly twice as much time. Carly indicated ample time on these two lessons, but indicated the use of outside materials during this time as well, and specifically noted that little time was spent on the activity *One to Another*: "this activity was assigned & asked to be finished as an on-going assignment whenever students had time in computer lab, but most never got to go back to it." *One to Another*, part of Lesson 3, was in some sense a "practice" activity: the topic of representational translations (translating graph/table/equation/narrative) had been established by the previous activity, and this activity gave student seven similar (but each uniquely challenging) problems to solve.

Recall that Gayle had originally planned to assign the pencil-and-paper activity *One to Another* as homework, but ended up spending more than a class period on it, most likely assigned homework on it, and some students spent additional time on it as well. There is no way to know for sure, but it could be that time on these particular activities, perhaps especially *One to Another*, which allowed opportunity for repeated practice of skills, made a difference.

6.6.2 Class Organization and Level of Directive Teaching

Gayle did not walk students through the material as Marilyn did, but there are other interesting aspects of Gayle's enactment. In her approach to the story activities of Lesson 5, she focused students on one-dimensional aspects of the graph (time and distance). Marilyn and Kate (Region A) as well as Carly (Region C) were also observed teaching lesson 5. None of these teachers required that time and distance details be featured in student stories.

All teachers expected students to write a story that corresponded to the graph of Wendella's journey, but both Gayle and Marilyn made sure all students knew the correct sequence of movements (steep meant road, horizontal meant quicksand, etc.) before allowing the students to write. While Gayle focused students on the numeric values of time and distance, Marilyn and Kate gave instructions that focused students on writing creatively. Carly, on the other hand, gave instructions and organized class time with a focus on graph interpretation. In Carly's class, students wrote stories and exchanged with a partner before running the simulation and discussing with the partner. Carly's subsequent whole group follow-up discussion, using a projected view of the software, focused on portions of the graph students found surprising, such as the segment of time when Wendella the dog stood still.

These differences in approach and focus could be considered important attributes relating to how teachers actually taught the lesson. Among the lesson 5 classroom observations, only Carly gave students individual opportunity to not only predict the movement from the graph, but also to test an individual prediction (their partner's) and discuss the results as a class. This distinction is typical of what was observed over the days of observation. Carly employed many opportunities, and other teachers some opportunities, to explore and discuss with the software, while Gayle often provided instructions, formulas, or evaluations of student work that circumvented the need to use the software productively.

Looking more generally at the unit, this contrast between Carly and Gayle can be further described. Carly and Gayle had similar overall gain scores, and yet emphasized very different things. Gayle's emphasis on *One to Another,* and her descriptions of spending extra time on "using the equations, with the table and process," and on plotting points in the classroom, might indicate she allowed more student time and attention to the mathematical skills typically taught in an 8^{th} grade curriculum (the M_1 skills of the unit), perhaps taught predominantly in a procedural manner. Carly, in contrast, did not spend class time on the paper-and-pencil activity *One to Another*, and in general spent a good deal of class time on concepts and connections, rather than focusing on numeric calculations.

Looking further, observations of Gayle's enactment, along with Gayle's description of how she taught the earlier lessons, suggest a limited use of the software and a correspondingly limited focus on the concept of motion, compared to the other case-study teachers. Most of the observed teachers refrained from providing students with formulas, instead focusing students on motion by asking for example "If the character is moving 3 meters every second, where is he at one second? 2 seconds?" without the benefit of the formula. Most likely, this approach appeared to be an attempt to encourage intuitive understanding. In contrast, Gayle focused students on a formulaic approach, frequently providing the formula "distance = rate * time" and encouraging students to apply it.

Despite Gayle's formulaic approach and limited use of the software, certain aspects of these qualities may have in fact played a role in her comparatively high M1 gains. At least, it is interesting to compare her approach with that of Sharon, with M2 gains close to treatment average but M1 gains almost a standard deviation below. Sharon, as noted, spent less time on the earlier lessons than Gayle, specifically lessons 3 and 4, but also used the SimCalc software more often, usually in what appeared to be productive ways focused on graphical interpretation. However, Sharon's enactment of a lesson 7 activity demonstrates that the software was also at least occasionally used as an unnecessary crutch, which in this case may have affected Sharon's M1 results.

Sharon's class was observed during Lesson 7, in which students were required to create an original graph of a crab's motion (going above or below water level) using the software, and then sketch the graph and write a corresponding equation. Students were observed copying the equation straight from the algebraic window, and Sharon was observed encouraging this solution method, rather than using the algebraic window to test student-generated equations. From her interview:

> **Q**: OK. Did you see the software help, affect their learning in any way?
>
> **Sharon**: Yes. I don't think they could have done, they couldn't have come up with those equations they could not have come up with the equations I don't think. Not the majority of them. Some of them could have, but the majority of them wouldn't have been able to come up with the equations I don't think without the software.

Sharon, for some reason, did not connect this activity with the activities from lessons 3 and 4, and the students therefore lost the opportunity re-practice those skills. Based on Sharon's interview, the students apparently generated their equations in lessons 3 and 4 strictly through pattern-matching with the corresponding table, and Sharon saw this lesson 7 activity as being much more difficult.

Marilyn's class was also observed doing this activity in lesson 7, and Marilyn also encouraged the students to obtain the equation from the algebraic window. Note that both Marilyn and Sharon had poor M1 gains.

Unfortunately, there is no observation data for Gayle's class for this lesson 7 activity. However, based on Gayle's limited focus on the software and observations of her enactment of a similar activity in lesson 4 (previously described in section 4.2), it seems unlikely Gayle would have encouraged her students to use the algebraic window to determine the equation. Rather, since the workbook did not explicitly say to use the software to even check the equation, she was more likely to ignore the algebraic window completely. As noted in the Lesson 5 analysis, Gayle focuses the students on particular solution methods, but she did not give out answers; students were expected to work out the solutions themselves.

6.7 Gayle's Distinctive features

Gayle's enactment of the unit materials was distinctive in several ways. She adhered to the curriculum more than most teachers, skipping very little, and based on analysis appeared to have given students more time than most other teachers to work on the materials on their own. While Sharon and Carly were close to Gayle in terms of curriculum adherence and allowing ample time, Gayle spent a good deal more time on the lessons focused on M1 skills (1-4 & 10) than the lessons focused on M2 skills (5-9), while Sharon and Carly spent about the same amount of time on each.

Gayle extended the time for the unit from her original lesson plan. Along with her colleagues at her school (recall every 8^{th} grade class was using the intervention), she apparently recognized students' struggles in the early lessons and provided extra time and assistance. Although other case-study teachers extended their time as well, this flexibility is in contrast to Marilyn, who spent considerably less time on the unit than her lesson plan had projected.

Gayle was also distinctive in some issues related to the level of directive teaching. She did not, in general, give students answers before allowing them time to work on the problem themselves (as did Marilyn), but she did offer instructions and provide formulas that focused student attention on certain solution methods. Looking specifically at Lesson 5, this issue manifests itself in Gayle repeatedly focusing students on one-dimensional aspects of the graph (computing the time and distance parameters for each leg of the journey). At the same time, the software was only used sparingly, which did little to emphasize the connection between graph and motion.

Chapter 7: Training

Issues of time, material coverage, classroom organization and directive teaching were not specifically emphasized in the training process by any of the workshop facilitators. However, the topics did come up, or were dealt with implicitly in a variety of ways. The following sections describe the training processes that appear to have influenced Marilyn's and Gayle's approach to these issues. These descriptions come from the TOT Workshop, the regional workshops and planning days these teachers attended, and trainer and teacher interviews. Chapter 8 will go into more detail concerning the links and disconnects between these events and the teachers' enactments, along with a discussion of implications.

7.1 Time and Material

7.1.1 The TOT Workshop

The TOT workshop included a discussion on the suggested time line included in the teacher's manual. The TOT facilitator acknowledged that the time limits were ambitious and the unit would likely take somewhat longer to complete, especially the first year. The facilitator also suggested that the trainers advise teachers on where to cut back if necessary. She states that these issues would be discussed later in the TOT workshop:

> **Facilitator**: We can talk about which lessons seem really crucial, which problems might you be able to skip, and so forth. Because like I said, they do not have to march through page by page.

The co-facilitator for the TOT workshop went on to say that this would be good to model for teachers, because she believes teachers should make these decisions with all of their resources:

> **Co-Facilitator**: You don't have to work every problem in the textbook. Decide which ones are most critical, which ones really hit at the heart of the task.

However, although the TOT facilitators alluded to teachers tailoring their lessons and skipping material, the promised discussion on what would be most appropriately skipped or modified never materialized.

7.1.2 Region A (Marilyn's region)

The issue of time was not a major topic during the Region A workshop, but timing considerations did come up. Before starting the unit, Trainer A gave the participating teachers time to "play" with the software, and emphasized that the students should be given ample time to do the same. As they prepared to begin the unit, the trainer explained that there were 10 lessons, designed to be completed in 10 days, but that the teachers' students and situation would dictate how fast or slowly they would actually go through the material. Modifications and extensions to the unit were discussed, but choosing particular material that could be most safely skipped was not a topic of discussion.

These issues were discussed more explicitly during Planning Day. One teacher, Wendy, had already experimented with the software in her Algebra I class, and shared her experiences with the group. The trainer asked if the one-day-per-lesson rule of thumb had worked, and Wendy said no, not always. Wendy and others agreed that three weeks was a better time estimate for completing the unit.

The decision to skip Lesson 6 was also discussed during the Planning Day. This idea originated with Wendy, who did not see this lesson as a building block within the unit. Trainer A encouraged the decision to leave Lesson 6 out if time was an issue.

Marilyn's original lesson plan was similar to the recommended time schedule. The consensus had been to plan about three weeks; Marilyn had scheduled 14 days. As part of this schedule, Marilyn included a class session using the CBR's (which was encouraged during the training workshop), and planned to skip Lesson 6 and parts of Lessons 9 and 10.

Trainer A joined this researcher in Marilyn's classroom during the first day of observation for this study. The following transcript, discussing Marilyn's decision to skip Lesson 6, comes from a videotaped discussion between Trainer A, Marilyn, and this researcher, following that observation:

> **Marilyn**: You don't need to know why we skipped this, right? [Lesson 6]
> **Researcher**: You can go ahead and tell me.
> **Marilyn**: Basically, it's money. I mean, we kind of stop the game deals, and this - [Marilyn looks at Trainer A]
> **Trainer A**: It's almost like it's not in the flow of things.
> **Marilyn**: Right.
> **Trainer A**: And so, when we had the lesson planning, you know, we just talked about, you know this is pretty comparable to that prior lesson. But, if you had additional time, then this would be a nice extension. OK. Or a nice review.
> **Marilyn**: Then we touch it here with the money issue [pointing to page 33 in the workbook *Mathematically Speaking: Graphs to Know*].
> [Trainer A agrees]
> **Marilyn**: We come back, and touch the money here. And this is what I think they need to see more so than, you know, the lesson. And again, time is an issue there. 'Cause I'm not going to be able to post-test until Monday.

7.1.3 Region B (Gayle's region)

In contrast to the Region A training, the region B workshop did not discuss what to skip or ways to extend or modify unit activities. Trainer B did, however, frequently suggest teachers think about how long lessons and activities would take. He recommended teachers allow students adequate time to "play" with the software before actually starting the unit. He recommended that teachers allow time for logistical issues such as getting students to the lab, and emphasized that teachers consider both the time students would need to *do* the activities and the whole group time needed to *discuss* the activities.

Trainer B refrained from explicitly telling the teachers how much time to allot for each lesson (at least during the workshop), but questioned them, specifically on lessons 1, 2, 3, and 5, on whether the time suggestions in the teacher's manual seemed sufficient for their classrooms. He did give some opinions, such as saying in reference to the lesson 2 suggestion timeline: *I don't know if that first part* [Question 2] *would take 20 minutes, but I think that second part* [Question 3] *is going to take every bit of 20 minutes.* In lesson 2 and lesson 5, he pointed out how much time the teachers themselves had spent working through the problems, and reminded them that the students would need even more time. He also pointed out that the teachers should decide which questions and/or activities to assign as homework, and that they would need to allow class time to discuss homework the following day.

Actual decisions about timing and homework were postponed until planning day. Although there is no observation data on the Region B planning day, Gayle reported during her interview that she and the other two participating teachers worked together that day as one group, along with Trainer B, resulting in very similar lesson plans among the teachers. According to Gayle, the group discussed which parts they thought students would struggle with, and they planned extra time accordingly.

Gayle's resulting lesson plan scheduled the first class period to introduce the unit and play with the program. She then allotted a day per lesson, except lessons 2, 3, and 5 were allotted two days each (recall these were lessons Trainer B had suggested might need more time). Certain activities were earmarked as homework assignments, including the entire activity *One to Another*.

7.2 Class Organization and Level of Directive Teaching

7.2.1 The TOT Workshop

During the TOT workshop the six workshop participants (the regional trainers) tended to function as one small group. Ideas were shared continuously: during the introduction to a new activity, while the trainers worked on the activity, and afterward as the group reflected on the activity just completed. Although the trainers worked in pairs somewhat, comments and suggestions (both from the participants and the facilitators) were frequently directed to the group at large even during small group work.

There were no explicit instructions to refrain from directive teaching, but this approach was certainly not modeled. When introducing the activity "Controlling Characters with Equation", the facilitator explicitly told the trainers that she will be leading them through the activity using a "whole class" approach. This referred to a whole class of teachers, not students. During this modeling experience, the answers to some of the questions were discussed, but the primary focus was on pedagogical considerations, and the facilitator remarked that students will likely need time to play around with and run the simulation to answer the workbook questions. Thus, despite discussing the answers, this modeling was not intended to suggest that the answers should be decided as a group in the actual classrooms.

With respect to Lesson 5, the TOT workshop focused on activity # 3 during whole group discussion. This is the activity in which the Wendella character turns around and runs backwards. The facilitators tell the trainers that this is an activity they will want to do with their teachers, and the teachers will want to work out with their students. This is an issue for class organization, in that the TOT facilitators put extra emphasis on this particular activity out of the five activities of the lesson.

7.2.2 Region A (Marilyn's region)

As in the TOT workshop, there were no explicit instructions during the Region A workshop concerning the issue of class organization or level of directive teaching. Teachers were not restricted from working through the materials with their students as a class, but this was not modeled by the trainer.

However, Trainer A did model extensively. Early in the workshop, before beginning the workbook lessons themselves, Trainer A informed the participating teachers that they would be going through the lessons as if she were teaching it to the students herself. At the same time, Trainer A also informed the teachers that 1) they will need to think about different scaffolding questions to ask so that students can discover different things, 2) the students need to use the software themselves in order to really understand the materials; and 3) at end of every session, teachers should conduct a whole group discussion with their class.

At the end of the three days, Trainer A reiterated that she had been modeling throughout the workshop. In closing, Trainer A put the following quote on the overhead:

> Children do not learn by doing … They learn by thinking, discussing, and reflecting on what they have done. -- William Speer (NCSM, 1997, ..)

She then commented:

> **Trainer A**: And I've tried to model, in this 3-day training, how we do spend some time going over those reflections. We did a lot of exploring, we did a lot of explaining, which I think is very critical to the understanding of mathematics … So, I hope I have modeled for you, over these three days, the things you should do for kids, the questions you should ask. And then, do that good Socratic questioning. I've tried to ask questions of everybody. You know, because you don't want to let one child just sit there in the back of the room ... and go unnoticed ...

Typically, at the beginning of each lesson Trainer A displayed and briefly discussed the "big ideas" of the lesson on an overhead. Trainer A created this overhead sheet from the big ideas provided in the teacher's guide for each lesson of the unit. Trainer A then modeled instruction, behaving as a teacher and allowing the teachers to be the students. The workbook text was read aloud, sometimes by Trainer A but often by a teacher, and then Trainer A often asked questions to aid and assess understanding of the read material. The teachers were then allowed to work through the exercises in pairs, with Trainer A roaming the classroom, helping if necessary in a scaffolding manner, asking the teachers questions as if they were students, and giving pedagogical advice. During follow-up discussions after teachers had worked on the exercises, Trainer A did not explicitly refer back to the "big ideas" of the lesson, but went over the answers and continued to ask the teachers questions as if they were students. A good deal of the follow-up time was often spent providing pedagogical advice rather than actually modeling a classroom discussion, but some modeling did occur. Trainer A continued in this mode throughout the workshop, often asking teachers conceptual questions both during small group work and during whole group introductory and follow-up episodes (examples of these behaviors will be provided in the Lesson 5 description below).

7.2.2.1 Lesson 5

The following describes Trainer A's approach to lesson 5 during the workshop, with an emphasis on ideas and behaviors that seem similar (or strikingly dissimilar) to Marilyn's enactment, especially features that may have affected Marilyn in terms of class organization and level of directive teaching. Paragraphs of analysis linking this experience to Marilyn's lesson 5 enactment are interspersed with the description:

Trainer A starts lesson 5 by displaying an overhead of the big ideas of the lesson (taken from the teacher's guide) and explaining them. They discuss the meaning of the term "multi-segment" and the fact that this indicates the character will have different movements in different pieces of the graph. Trainer A emphasizes one big idea by saying:

> **Trainer A**: I like this statement: graphs tell us a story and a story could be told by a graph. So we're going to practice telling a story based on what the graph looks like. OK. I like this activity in that the kids' creativity really comes out.

The trainer continues with the other big ideas ("flat lines represent standing still" and "Lines 'slanting downwards' represent moving backward").

<u>Analysis:</u> Note that Marilyn exposed her students to all of these ideas. Marilyn tells her class "it's a story about a graph" and "that graph tells a story," and she encouraged creativity in the stories. The motion of horizontal lines is introduced. Backwards motion is introduced, although Marilyn most often connected forward-backward motion with an inverted "V" on the graph, rather than focusing specifically on the segment 'slanting downwards' representing backwards motion.

Trainer A reads the activity description to the class, and then reads the story that she had written in the TOT workshop. It is a creative story not limited to the road/swamp/quicksand storyline. Trainer A points out that in her story, she says Wendella goes in a different direction for the last leg, but that's not correct, she actually keeps going fast in the same direction. She then instructs the teachers to write a story without being limited to the suggested story-line, and to share it with their partner.

Trainer A walks from pair to pair, suggesting to at least some teachers (including Marilyn) that they use the step function to compare the story and the graph. Teachers do so, but there is no subsequent discussion.

Analysis: It is interesting to note that the step function is introduced and explored at the beginning of the workshop, but this is the only activity in which Trainer A is observed specifically encouraging its use. The step function seems somewhat counter-productive for this particular exercise, where it is important to see the character run, move more slowly, and stop. Marilyn, similarly, suggested that students use the step function for this activity, and does not encourage it at any other time during observations.

Trainer A reads activity #2A with the class. She then asks "is there anything I can do to help you understand your task?" No one responds, and teachers start to work on #2A in pairs. After a while, Trainer A reads part B of activity #2 out loud. While the teachers are working in pairs, Trainer A walks around and sometimes stops to work with specific teachers. While working with Marilyn on part B, Marilyn has written "2 min" for the 2nd segment, and Trainer A asks “How do you know it was two minutes?” and later asks “So, how fast was she going?”

Trainer A conducts a whole group discussion after the teachers have completed activity #2:

> **Trainer A**: Did anyone have any trouble with 2 B? [pause]. Did they maintain constant speed?
> **Teachers**: No.
> **Trainer A**: No. That’s why it’s multi-segment. OK?
> **Trainer A**: Then it says, on C, [pause]. Let me go back just a minute. Was there any time on the graph when she had the same speed? Tell me when.
> [Many teachers speak at once, saying: the first and 4th segments (road) and the times she’s in the swamp are the same, too.]
> Trainer A: So looking at those 2 same speeds, what can you tell me about those segments?
> **Teacher** (off-camera): Well, the road was the steeper segment.
> **Trainer A**: OK. I’m just talking about the two with the same speed.
> **Teacher** (off-camera): They’re parallel.
> **Trainer A**: They’re parallel, right? [Trainer A discusses that briefly]
> **Trainer A**: When is she going the fastest?
> **Teachers**: On the road.
> **Trainer A**: And what was her unit rate?
> [Many teachers talk at once. Someone says 300 meters per minute]
> **Trainer A**: OK. 300 meters per? [pause] Per minute.

They move on to part C, and discuss the 4th segment as a group. Trainer A points out to be careful to use the correct units.

<u>Analysis:</u> Recall that Trainer A said at the beginning of the workshop they would be going through the workbook as if she were the teacher. However, in terms of class organization and level of directive teaching, her enactment is quite different from Marilyn’s. Trainer A’s introductions are short, and are not directive. They do not include doing any part of the problem together as an example. Trainer A does, however, offer assistance if necessary (“is there anything I can do to help you understand your

task?”). Her follow-up discussions discuss every answer and probe more deeply with further questions as well.

Trainer A then moves on to activity #3, which uses the file Wendella3.smw. She tells them to predict first -- what is happening in that graph? Teachers can be heard talking to one another, perhaps predicting. Then Trainer A displays the graph as an overhead, using a Powerpoint slide (NOT the software).

Trainer A: Somebody tell me in words what’s happening in this first segment
Wendy: She’s in the swamp.
Trainer A: OK. She’s in the swamp.
Wendy: Then she’s running on the road.
Trainer A [off-camera]: Here?
Wendy: Yes
Trainer A: OK. She’s running on the road. Fast or slow?
Wendy (and other teachers): Fast.
Trainer A: Very fast.
Wendy: And then, she needed to turn around and go back.
Trainer A: OK.
Wendy: She ran back.
Trainer A: Very fast again, right?
Wendy: And then she’s back in the swamp.
[Other teachers are calling out the same answers as Wendy speaks]
Trainer A: So, is this fast or slow here?
Teachers: slow
Trainer A: Is it faster or slower than this one? [graph is off-camera.]
Teachers: Same
Trainer A: How do you know it’s the same?
Teacher1: Same steepness
Teacher2: Four minutes and a hundred meters, and two three four and a hundred meters.
Trainer A: OK. And again, you want to ask kids those kinds of questions, so they were traveling at the same rate here, but it was slower than both of these. OK? Tell me about this segment here.
Teacher: <inaudible>
Wendy: Going back to where they left the swamp.
Trainer A: OK. So, we might have to talk to kids about here, that really distance is not directional, that it looks here like I’m doing what? I’m going -- further away [gestures away from her body with her arm], but

> I’ve got to remember over here, that I’m working with this y-axis, and my distance was at maximum of 700 meters, but then it decreased to 100 meters. [Camera shows the projected graph, with a laser pointer pointing to the points (6,700) and (8,100) as **Trainer A** speaks].
> **Marilyn**: A lot of the time they’ll have that down, and they don’t remember that time doesn’t stop.
> **Trainer A**: Yeah.
> **Kate**: They’ll just go like that [gestures a vertical line].
> **Marilyn**: <inaudible> time is still going on.

<u>Analysis:</u> Trainer A repeatedly told the workshop participants that students need to predict before running the software. In this lesson, she models making the prediction as a whole group; there is no modeling of a whole group discussion after <u>testing</u> a (perhaps incorrect) prediction. Similarly, Marilyn conducted a (correct) class prediction for the first Lesson 5 activity with no subsequent discussion. For activity #3, Marilyn did not explicitly tell the students to predict before running the simulation. Still, some of her students expressed surprise at the motion, thus indicating some sort of pre-existing thoughts and expectations. Recall that Marilyn’s response was to say “There’s still time. Time is still passing by” (note the similarity with her own final comment in the above discussion), and to encourage an explanation that the dog went back to get a bone. Although Trainer A references the graph to explain the motion-graph connection, Marilyn made no explicit reference to the graph during this activity in the classroom.

Kate suggests using a graphing calculator and a CBR (Calculator-Based Ranger) so the students could walk the motion from this activity. A short discussion ensues on the effectiveness of using the CBR. Trainer A encourages the idea, suggesting the teachers note in their workbooks to use the CBRs with this lesson, and promises to bring out a set of CBRs to work with the next workshop day (which she does).

Analysis: Marilyn has students work with CBRs with a substitute teacher the day before Lesson 5 is introduced. However, students are confused by the backwards motion of the Wendella character, and the connections between the two experiences are not explored.

Trainer A continues the follow-up discussion for activity #3, reading part B and later part C and part D aloud and allowing the teachers to answer the questions.

Analysis: Note that, while both Trainer A and Marilyn suggests using the "step" function for activity #1, neither suggests its use for this activity, where one might argue, it could be more effectively used. More importantly, from the standpoint of class organization, note that Marilyn conducted little introduction and no formal follow-up to this activity, while Trainer A went over this activity very carefully. Based on subsequent observations, it is likely Marilyn might have conducted some sort of follow-up during TAKS time had she not taken time for the after-class interview, although this would not have included the six students who do not attend that class. The TOT workshop had instructed the trainers to emphasize this activity, and Trainer A did so, but she did not explicitly tell the teachers to do the same.

The workshop continues with activity #4. Trainer A reads the instructions to the activity, one of the teachers talks about how to use the hot spots to change the graph, and teachers once again work in pairs. As they work, Trainer A interacts with individual teachers. There is no whole group follow-up after this small group work.

Analysis: Marilyn’s class never gets to activity #4.

7.2.3 Region B (Gayle’s region)

As with the TOT and Region A workshops, there were no explicit instructions during the Region B workshop concerning the issues of class organization and level of directive teaching. Trainer B did model instruction as the workshop began, but stopped this technique after the first day of the three-day workshop. Toward the end of the workshop, he talked with his teachers about this decision, pointing out the importance of whole group class discussions, even though he did not model them extensively:

> **Trainer B**: Now, I didn't do that so much with you all, because you are the teachers, and maybe I should've modeled that a little more, but I didn't. We didn't have a whole lot of whole-group discussion after day 1. I tried to make a point in Day 1 of going through some of it with you, getting you started, and then letting you go. I didn't feel the need, since you were instructors yourselves, of doing that on every one of the activities. I thought it was very important that you have an opportunity to work through the lessons so that you could look for any trouble places or things that you think that your kids might have a problem with. But whole-group instruction, I think, does need to be considered and built in there as you're doing your lesson plans.

During his interview, Trainer B spoke specifically about the importance of student autonomy, discussing his philosophy and how that played out in the workshop:

> **Q**: Is there any specific pedagogical ideas that you especially tried to target during the workshop?
>
> **Trainer B**: What I wound up modeling was the idea that if kids are successful I think and they're able to travel on, leave them alone and let them do it. We are supposed to be facilitators in learning. And as long as they're being successful, I can reinforce that. But I think sometimes we want to control too much. And I had four good learners there. So they were able to once I get them started, and let's read the scenario, let's think about it. Now then, let's work through the activities. And I hope that they'll allow their students to do that. The freedom to learn the way they learn.

> **Q**: Why did you target that idea in particular?
>
> **Trainer B**: Because I think sometimes that educators are controllers and they want to be in control of the learning and sometimes they want to see the learning done this way because that's the way they learned how to do it. And we're learning more in our brain research about all students do not learn the same way. And to allow them that freedom on the computer to be able to change and move and do some things at their own rates.

Trainer B spoke well of the four participating teachers in the workshop, and did say that his limited-control approach was based on their overall competence, and would have been modified had he seen any of them struggling with the material or software. He looked over the teacher's shoulders as they worked through the unit materials, but he did not model questioning techniques during this time as did the Region A workshop trainer. Trainer B did conduct follow-up whole group discussions after every lesson once the teachers had worked through that particular lesson, but after the first day, the discussions were trainer-to-teacher rather than modeling a teacher-student format.

Gayle said very little during workshop whole group discussions. In fact, the two more-experienced of the four participating teachers dominated most conversations. Trainer B never directed questions at anyone in particular, and one teacher answered most of the questions he posed. The other experienced teacher (Sharon) asked many questions and offered many suggestions and comments.

Although Trainer B talks about giving the teachers time to work through the activities, the time spent on the materials without trainer-to-teacher talk was actually limited. Only 151 minutes (22%) of the workshop time was devoted to small group or individual work. Over the course of the three-day workshop, Trainer B spent 545 minutes in whole group discussion with his teachers, compared to 351 minutes spent similarly in Region A and 278 spent in Region C. During this time, his discussions not only pertained to the SimCalc unit, but covered a gamut of professional development considerations, all useful for his teachers but often only loosely tied to the immediate issue at hand.

Trainer B repeatedly stressed during the workshop the importance of having and using a common visual of some sort. At first, he said that an ELMO or color transparencies would suffice, but towards the end of the workshop, he stressed the need for a projected version of the software:

> **Trainer B**: As a facilitator of the SimCalc project, I need to be sure that you all have what you need to use to present this unit. The ELMO is nice, except you won't be able to show motion, because that's just a screen to use like an overhead unit. So we need to talk about that sometime today.

Trainer B offered to loan an In-Focus (LCD) projector to whoever needed it. At the time, Gayle said she could check one out at her school.

7.2.3.1 Lesson 5

Recall that Gayle's enactment of the unit materials entailed a certain level of directive teaching in that she often directed student's focus on specific details or the use of specific formulas and solution methods. In Lesson 5, she focuses student attention on the time and distance "of each line segment" in the graphs depicting Wendella the dog's motion.

The following describes Trainer B's approach to lesson 5 during the workshop, with an emphasis on the features that may have affected Gayle in terms of class organization and level of directive teaching. Paragraphs of analysis are interspersed with the description, with an overall analysis at the end:

Trainer B introduces the lesson by discussing it briefly. He talks about piecewise functions and the type of motion that can be represented through such functions, and mentions that these concepts are developed in this unit in a manner similar to the approach taken in TEXTEAMS (Texas Teachers Empowered in Mathematics and Science) materials. Gayle discovers how to manipulate the graph and make the Wendella character go backwards, and shares this by demonstrating using the projector setup.

Trainer B then allows the teachers to work through the first activity. One teacher questions the instructions “Open but do not run the file for Wendella’s first journey, *Wendella1.smw*.” Another teacher suggests students be allowed to run the simulation after they have written their stories. Trainer B agrees, saying “And follow your story, and see if it makes sense.”

<u>Analysis:</u> This is the first of many references Trainer B makes concerning the importance of linking the story to the corresponding graph.

After the teachers write their stories, they are read aloud. After the first story, the discussion is about the importance of developing student’s verbal skills in the context of mathematics. After the third story, Trainer B asks “What did <teacher’s name> interject in her story, near the end, that would be very important, if I’m trying to draw a graph?” There is a discussion of the fact that most of the stories said nothing about the lengths of time, so you couldn’t draw the graph from the stories.

> **Trainer B**: One of the themes that we have to make sure we point out to the students is and notice I didn’t say anything to either one of you [first teachers to read]. I waited until [teacher] mentioned a time frame, and asked because I don’t want to slam your story. It was a very nice story.

> But if I'm trying to take the story and relate it to a graph, then one of the things that was missing was the length of time for each of those things.

<u>Analysis:</u> Recall that Gayle had written in her lesson plan: "share stories, talk about what's missing."

After listening to another story, Trainer B continues with more important information to include in the story writing:

> **Trainer B**: Here's something else to think about. Have you pinpointed in the graph where you would start and where you would stop? Do I know your distances from your story? So, you need to not only say something about time, but also about distances. So, why don't you refine your stories?

<u>Analysis:</u> There is certainly a similarity between Gayle's enactment and this part of her training experience. Gayle told her students to include time calculations in their first Wendella story, and, according to her interview, had hoped someone would include distance calculations as well. Since no one did so, Gayle points that out after the stories had been read ("Did any group talk about the distance traveled? No, so we could be more specific"), and instructs the class to include distance calculations in their next stories.

At this point, the teachers refined their stories to include distance information. One teacher reads her refined story, and Trainer B asks "Now could you draw a graph from that description?" The teachers agree that, yes, you could, if you assume the character started at zero. Trainer B responds with the following:

> **Trainer B**: So, would it matter then, what the graph would look like, if they decided, well, maybe I could start at 100? What would be true about the graph if I started at 100 compared to if I started at zero? … Suppose I started here [pointing to 100 on the projected graph], since it doesn't say in your story to start at zero. So, how would the graph, starting out here, compare with the graph starting at zero?

The story is then re-read, with Trainer B using his finger to draw a corresponding graph on the overhead graph, starting at y=100. One of the teachers (not Gayle) points out that the graph Trainer B is tracing is parallel to the actual graph of the character's motion. Trainer B comments:

> **Trainer B**: Now, won't that start inching them into translations? So actually, we could start at anywhere with her instructions, and we would have drawn a graph that would have paralleled this graph. It would have just been translated up 100 or 200, or wherever I started from.

<u>Analysis:</u> While Trainer B is explicitly relating one of the refined stories from the first activity back to the graph, Gayle makes no similar connections during her enactment, in fact never explicitly referencing a graph after any of the many stories read aloud in her class. Since Gayle is quiet during the above interchange (as she is for most whole group discussions during the workshop), it is unclear how she interprets this example. Since her MKT score was quite low, it is possible that her experience with translations is limited and this example was not as helpful as Trainer B assumed.

Another teacher reads her story, with Trainer B again starting to trace the graph as she reads. The teacher starts off her story saying Wendella the dog ran quickly for 1 minute. Trainer B moves his finger slightly differently from the actual graph, saying "All ‘quicklys’ are not created equal”, but the teacher clarifies, explaining that she goes on with her story, saying “After she had gone 300 meters she …”. Trainer B acknowledges this quickly, but is then distracted because lunch is served, and does not continue to follow the graph and the story.

After lunch, Trainer B points out that most of the questions in the workbook activities have three questions: how far does the character travel, how long does he travel, and what is the rate? He then points to the first segment of the graph:

> **Trainer B**: So, if we said something like, see this piece right here? [Trainer B is pointing at the screen, using the cursor, but it cannot be seen on-camera] I could say, well, she traveled at a rate of what?
> Teachers and Trainer B together: 300 meters per minute
> **Trainer B**: For …
> Teachers and Trainer B: One minute
> **Trainer B**: That shortens it pretty short and sweet then, huh?

<u>Analysis:</u> Trainer B appears to be demonstrating an alternative way to describe the first leg of the character's journey. Based on Gayle's comments, both at the end of her enactment of Lesson 5 and in her interview, it is possible that she interprets Trainer B's comments on speed to mean that speed is required <u>in addition to time and distance</u> in order to recreate a graph from a given story.

Trainer B skips the second activity (p. 25), which is strictly a paper-and-pencil activity, and moves on to activity 3 (p. 26), which uses the file *Wendella3*. He tells the teachers to write a story based on the given graph, with the following additional instructions:

> **Trainer B**: This time, Wendella runs back towards where she started. And does she go all the way back? And how can you tell? These are the things to be thinking about when you write your story.

After a teacher reads her story, Trainer B explains that he made the graph on the overhead larger so it could be easily seen, and tells the teachers to note that as the teacher read her story, you could just follow the flow with the graph.

<u>Analysis:</u> Note that Trainer B has repeatedly emphasized the connection between the story and the graph, but never finished a simple explicit example. He does not refer to the graph until the teachers have added both time and distance parameters in their stories. Then, in his first example, he traces a translation. The second example was interrupted by lunch. In this last example, after a teacher reads a story from the Wendella3 graph, Trainer B notes that you could follow the flow of the story with the graph, but he does not explicitly do so.

The group discusses whether or not there was enough information in the story to re-create the graph. The story had said Wendella is chased by a "bad dog" back to the swamp, with no time and distance information, and the group discusses whether or not Wendella might be traveling back at the same speed it had been going forward. The discussion is not modeled as it would play out in the classroom, e.g., there is no explicit reference to the graph, and there is no discussion of why knowing Wendella's backwards speed, along with the fact that Wendella goes back to the swamp, would be sufficient information to re-create that part of the graph. Trainer B sums up this discussion by saying:

> **Trainer B:** Conversations like that with the kids, to let them express 'what am I seeing there', and to answer some of those questions that you

> might prompt. How could we tell the dog was chased back to the same place? What on the graph tells me that? And did she run faster back because the dog was chasing her or not, and how do you know?

Analysis: These more interpretive connections are missing from Gayle's enactment.

Using the common visual, Trainer B also has the group compare the speed of the character during the various legs of the journey, pointing out (using visual inspection) that Wendella the dog is traveling the same speed when moving quickly, whether going forward or backward, and also the same speed in the two legs going more slowly.

Analysis: Although Gayle does encourage her students to include speed in their stories, she does not encourage visual inspections such as this. As was noted earlier, only one student story in her class noted that Wendella was moving quickly when traveling backwards, and this observation was not discussed.

Trainer B moves more quickly through activities #4 and #5, having the teachers create a graph for activity #4 and think about the complexity of a corresponding story, but skipping the rest. Instead, he spends time discussing how much time the lesson might require in the classroom, and discussing how to choose students to share their stories. Trainer B talks about the creative opportunities of the lesson and emphasizes the importance of letting some student read their stories aloud because students will learn from each other.

Analysis: As discussed in the earlier section, Gayle allots two days for this lesson, which seems to come from her training. It is also possible that her focus on having students read their story aloud comes from Trainer B's emphasizing its importance.

Overall analysis:

Gayle's implementation of the lesson followed Trainer B's suggestions only in certain ways, perhaps leading to a higher level of directive teaching than Trainer B had intended. From this description, it seems reasonable to assume that Trainer B wanted the distance and time calculations included in the stories in order to explicitly relate the stories back to the graph, as part of the learning experience. In Gayle's implementation, students are simply directed to include these parameters, and follow-ups are focused on checking that this directive was followed, apparently in case a theoretical reader might want to sketch the graph from the story. Actually making connections from the stories back to the original graph is not a part of the enactment, nor are the deeper graphical interpretations discussed in the workshop.

Although Trainer B provided the means to a richer implementation of lesson 5, Gayle's covered all the “big ideas” stated in the teacher's guide (these were listed in section 5.3.1), and, other than perhaps implying that speed is needed along with distance and time in order to re-create a graph, did not communicate any mis-information. Students were also given repeated practice in calculating one-dimensional aspects of a multi-segment graph (in this case, distance and time), as well as speed (from the completed workbook exercises).

Chapter 8: Discussion

8.1 Marilyn

It is important to find and reflect on what might be distinctive and critical features of Marilyn's specific implementation. Despite emphasizing the big ideas of the unit and expressing a positive view about the intervention, Marilyn's overall gain scores were lower than 70% of the control group.

8.1.1 Apparent Links and Disconnects to the Training

In terms of time and materials, Marilyn did seem to be influenced by her workshop and planning day experiences. According to her daily log, she allowed some "play time" with the software on the first day; the workshop had suggested students be given "play time" with the software before beginning the unit. During planning day the workshop group agreed the unit would take about three weeks; Marilyn planned 14 days. This included a day using the CBRs; Trainer A had suggested using CBRs with the unit. Marilyn also skipped Lesson 6 completely, as Trainer A recommended during the Planning Day if time was an issue.

Although Marilyn planned 14 days for the unit, this was shortened by three days for various reasons. This decision does not seem to be connected to her training. Marilyn started the unit after Thanksgiving break, and wished to complete it before the winter holiday. The lost days, within these parameters, seemed to be due to situational conditions.

Based on the common interview with Trainer A and Marilyn, it is clear Marilyn's decision to skip Lesson 6 is linked to her training. The other material she originally planned to skip (parts of lessons 9 and 10) was likely influenced by training as well. However, her actual enactment skipped much more than that. These are only linked to training in the sense of omission: the workshop provided no advice on which lesson activities were most important, so it is perhaps not surprising that Marilyn went through each lesson sequentially, and thus the last activities of lessons were skipped due to time constraints.

With respect to the issues of class organization and level of directive teaching, there is little to indicate that Marilyn's enactment was significantly affected by her training experiences. Marilyn's ratio of whole group to small group time was about 50/50, which in fact was similar to her experience in the Region A workshop. However, more than 80% of Marilyn's whole group discussions on an activity were conducted before students had the opportunity to attempt the activities themselves, a situation quite different from her workshop experiences. During the three days of observation, Marilyn always worked out the first page or two of the day's lesson together as a class, providing students with many workbook answers, and one specific way to do the activities. This level of directive teaching was not modeled by Trainer A; Trainer A modeled a format in which the activity instructions are read aloud, the teacher makes sure the students understand the instructions, and the students are allowed to work on the activity individually or in pairs/groups. Trainer A also modeled a follow-up routine in which answers to workbook problems, as well as deeper questions posed by the teacher, were discussed. Marilyn did not have similar follow-up episodes, in fact during the three days of observation she included very little follow-up during her regular classroom time.

It would be inaccurate, however, to state that Marilyn was not influenced pedagogically by her training experiences. During her interview, she comments on the influence of Trainer A's questioning techniques, especially in the context of the unit:

> **Q**: Has this unit affected the way you teach?
>
> **Marilyn**: Process-wise, probably more questioning maybe has come into it. The, is, maybe question a little more. Ask the students more. I try to do that anyway with my other lessons but this gives you more opportunity to do that. So
>
> **Q**: Can you give me an example of what came to mind?
>
> **Marilyn**: Well, let me think. Like one of the students yesterday was asking, how do I put this into an equation? So I went to the graph and kind of led her into it. Yeah, you know. So what do we put in front? What is our speed? I go from there. That type of thing. Is maybe taking questions to get her to write that equation. That type of thing, instead of just saying, here's your equation, let's match things up and everything. There was more questioning from the, because I had the graph to look at. We had the simulation and then we had the table and so we had, I could question, carry them from one to another with questions if that makes sense. Kind of.
>
> … (*later in the interview)* …
>
> **Q**: Are there any other ideas or practices that you picked up from the workshop that really helped you teach this unit? …
>
> **Marilyn**: … I think the questioning is what I really got out of the workshop. Being able, going around and doing the questioning and bringing those type, using the graph and the scenes and the characters and all, and using the line of questioning to get that student to come up with the answers. That has helped me with the questioning. Of course it's always nice to have something they can look at. So that they can actually make sense of something like I said. And the questioning comes easier when they have that visual.

Thus, although Marilyn did not pick up on Trainer A's deeper and more conceptual questioning, she did use the experience to move beyond her usual approach, which, based on these interview comments, may have been even more directive.

8.1.2 Analysis

8.1.2.1 How distinctive features played a role

Of course, it is impossible to isolate exactly what led to Marilyn's class having such limited gain scores compared to both the treatment and control groups. However, analysis suggests the underlying themes of time, material, class organization and level of directive teaching seem to be attributes that distinguish Marilyn from the rest of the case-study sample, and may have played a role in her student's limited performance.

Certainly, spending less time on the unit than other classes may have put Marilyn's class at a disadvantage; students need time to learn. Marilyn is not the only example in this sub-study to suggest that inadequate time might be detrimental. If Marilyn's TAKS time is included in her total, then Kate (and only Kate) spent less time on the unit than Marilyn. Although Kate's class' average gain score was similar to the others in this sub-study, consider that her class was a high-achieving class of Algebra I students with an average pre-test score a standard deviation above the treatment average. Yet, Kate's class had a teacher-level gain score below both the treatment average and the case-study sample average. This is not likely due to the ceiling effect; Kate's class gain score was less than all treatment classes with similar pre-test scores.

Perhaps as a result of limited time, Marilyn's students had limited access to the material; Marilyn skipped more activities and more complete lessons than any other case-study teacher. This also may have put Marilyn's students at a disadvantage; one cannot learn what one is not exposed to.

Marilyn's class organization may also have been a factor affecting student performance. As discussed in Chapter 3, The TIMSS 1999 study defined three purposes of different lesson segments: *reviewing, introducing new content,* and *practicing new content*. Marilyn's teaching style may reflect this prevalent breakdown of class time. She may have considered the careful whole-class work with early activities as a way of *introducing new content*, and considered the rest of the lesson as practice. It should be noted that the SimCalc unit was not designed to be used in this format. Each workbook activity introduces a new challenge; thus leading students carefully through the earliest material of a lesson does not necessarily prepare them to solve the rest of it in a similar manner.

Furthermore, Marilyn's prolonged introductions took up a considerable amount of time, leaving less time for student independent work on the remaining activities, as well as time for follow-up. Based on analysis, Marilyn's class was likely given substantially less time to work independently than the other case-study classrooms, thus limiting student opportunity to solve problems independently from the teacher, and to use the software and curriculum to explore, discover, and reflect.

Perhaps even more importantly, follow-up time in Marilyn's class was very scarce, especially for those students who did not attend the subsequent TAKS class. It is possible students may have found it difficult to follow the thread of ideas from activity to activity, and lesson to lesson, with so little time spent on post-activity reflection. Furthermore, the lack of follow-up doesn't allow for simple feedback; at least for the three days of observation, it appears students were given little feedback on the work they completed independently.

And finally, Marilyn's very directive teaching approach may have affected student performance. The first page or two of every lesson was completed as a class, with Marilyn leading the discussion and supplying a great deal of information. Furthermore, although students did call out answers, most often no particular student was called upon; it appeared the same student or students supplied most of the answers. Any student who wished to could simply copy the answers into his/her workbook. During independent work time, when Marilyn helped a student, she often took over the computer mouse and showed the student how to do the problem.

It is important to point out that the average class M1 gain in Marilyn's class was slightly negative (-0.1), and the M2 average gain was small (more than a standard deviation below treatment teacher-level average) but at least positive and above the control group average gain. This might indicate that, despite limitations, some students were able to pick up on some of the conceptually more difficult aspects of the intervention. Still, it appears Marilyn's style of walking through the early lesson material as a class and then having students continue independently may not have provided most or all students adequate time for individual thought and practice nor the necessary feedback to master the skills.

8.1.2.2 How training played a role

Marilyn did appear to follow suggestions from the training on how much time to allow for the unit, and what to plan to skip due to time considerations. Her plans were similar to the other teacher's plans, yet the others extended the time as necessary whereas Marilyn shortened the time. It is not clear if training in any way influenced Marilyn's decision to schedule the unit between Thanksgiving and the winter holiday, with no "wiggle room" for unexpected learning or administrative delays.

Other than Lesson 6, Marilyn's training experience did not provide particular suggestions concerning what could be safely skipped, which may account for Marilyn's approach to the other lessons, which was to simply do as much as she could in a day and stop, rather than carefully picking and choosing the critical problems that "really hit at the heart of the task", as the co-facilitator suggested during the TOT training. This is an interesting point. The TOT facilitators were prepared and had every intention of giving information to the regional trainers about which activities were critical; it was a simple oversight that this did not occur. Up until a recent discussion with the leading TOT facilitator, she was unaware of this accidental omission. This TOT facilitator indicated that skipping all of Lesson 6 would not have been recommended.

Marilyn's decision to include a day of CBR exploration most likely was a result of her training experiences. Although this may have been beneficial, one might argue that in this case, with such limited time, adhering to the unit curriculum may have been a better decision. Recall that students were still surprised and confused by Wendella the dog's backwards motion, despite the recent CBR experience. Trainer A did not model how to connect these experiences with the SimCalc experiences, and Marilyn made little attempt to do so. Also, there was then no time left to finish the subsequent activities in the lesson, which may have helped solidify the connections. One must remember, however, that the CBR experience was led by a substitute teacher; it is possible the CBR experience may have been more productive with Marilyn present.

The other features of Marilyn's class that seem distinctive do not appear to have come from her training. Trainer A made it clear that she was modeling how one might teach the unit. Neither through this modeling, nor through any explicit instructions, did

Trainer A promote working through the material as a class, skipping a great deal of material, or failing to provide follow-up discussions for the entire class. Also, Trainer A did not take over the computer mouse when working individually with teachers as Marilyn was observed doing with her students.

8.1.2.3 Implications

Marilyn did seem to acquire a great deal from the workshop trainings, in ways that do not distinguish her from the other case-study teachers but should still be noted. She started the unit with reasonable lesson plans and timing estimations. She was comfortable with the software, and decided to enrich the curriculum with the CBR's, as was suggested in the workshop. Her interview indicated that she valued the questioning techniques used by the facilitator during the training sessions and tried to emulate it. During the three days of observation, Marilyn included the big ideas of the lessons and presented the mathematics in a format similar to the format used in the training workshop she attended. This perhaps privileged a certain way of approaching the activities, but at least provided students with one accurate approach.

And yet, her students had very limited learning gains, compared to almost all the remaining treatment sample.

It would appear success, at the level of the majority of the treatment sample, might require some minimal features of implementation. This analysis of Marilyn's enactment suggests these minimal features might include adequate time, adequate coverage of the workbook material, and adequate student autonomy.

8.2 Gayle

Gayle represents a somewhat surprisingly successful case. Despite reportedly low Mathematical Knowledge for Teaching and limitations in her enactment, Gayle led her class to produce some very respectable and in some ways outstanding performance results. Her class's overall gain score was the highest of the case-study sample, and higher than the treatment average. She had higher M1 gains than any of the other case-study teachers and at the same time did fairly well (and better than some) in M2. Compared across the larger study, her M1 gain score was more than a standard deviation above the treatment average, and more than 2 ½ times the control average. While not nearly as impressive, her M2 gains are within half a standard deviation of the treatment average, and still three times the average M2 gain of the control classrooms.

In terms of raw scores (as opposed to gain scores), it is interesting to note that Gayle started with a class of average achieving students who were, according to the testing instrument, somewhat below average in M1 skills and somewhat above average in M2 skills. Through her enactment of the unit, Gayle managed to pull this class up to be above the average in both types of skills.

8.2.1 Apparent Links and Disconnects to the Training

Our data indicates that Gayle's workshop and planning day experiences did seem to have an influence on her lesson plans in terms of the amount of time allotted. With respect to the actual enactment, she did not end up teaching, for instance, lesson 5 in exactly two class sessions, but she did follow her plans in terms of minutes per lesson for most lessons, even if that time was spread over more days than planned. There is no way to know whether Gayle intentionally allotted class time based on her lesson plan, or if the plan accurately estimated how much time would be required to work through the material. In either case, training provided Gayle with an appropriate time-line to successfully navigate through almost all the material.

The extra time Gayle spent on the earlier lessons (Lessons 1-4) was partially built into the lesson plan, since both lesson 2 and lesson 3 were allocated two classroom sessions each. But the lesson 3 activity *One to Another*, originally planned as a homework assignment, extended lesson 3 an additional session and more. This decision appears to have had little to do with her workshop training; in fact, based on her interview, it is quite possible that her supervisor made this decision. Since the supervisor had not gone through SimCalc training, he or she may have been most comfortable with the M1 materials, or may have considered them the bottom line due to the 8th grade TAKS test. It is also possible, since the class was relatively weak in M1 skills and rather strong in M2 skills (based on the pre-test scores), that Gayle and/or her supervisor might have been aware of these strengths and weaknesses and purposely focused attention where most necessary.

With respect to the issue of directive teaching, Trainer B felt that he was modeling a classroom atmosphere with extensive student autonomy, so that students could have “the freedom to learn the way they learn.” In some ways, Gayle did carry that out. She did not give students answers when introducing activities, and she allowed students a good percentage of class time to work on the material themselves. She was directive, however, in the sense of focusing attention on certain aspects and approaches to the unit, although that was not necessarily her intent.

In fact, if her lesson 5 enactment is a good indication, Gayle's intent may have been to follow the example of her training experiences. It seems quite likely that Gayle’s focus on the time and distance parameters came from her SimCalc training. Gayle had written in her lesson plans to “share stories; talk about what's missing.” Just as Trainer B had pointed out in the workshop that the teacher's stories were missing time and distance information, Gayle pointed this out to her students as well. Although Trainer B emphasized including the time and distance of each leg of the journey and then related it back to the graph, Gayle, in contrast, did not refer back to the graph, but rather emphasized including the time, distance, and rate calculations, so that someone *could* recreate the graph from the story if they wanted to. Gayle seemed unaware of this difference in emphasis; in her interview she stated that she believed she enacted the lesson as intended.

Furthermore, during the workshop Trainer B attempted to show that rate is another way to describe motion, but it was not clear from her enactment whether or not Gayle understood it as an *alternative* rather than another piece of essential information, along with time and distance, needed to recreate a graph. Gayle stated in her interview that this piece of her enactment was not connected to her workshop training, but her reference to “their fast might not be somebody else’s fast” is similar to Trainer B’s comment “all ‘quicklys’ are not created equal”. When Trainer B made that comment in the workshop, Sharon clarified that she had said ‘quickly’ but also specified both time and distance in her story. However, there was no attempt to make sure that everyone in the workshop understood why this made the ‘quickly’ reference specific enough.

Thus, Gayle's approach to lesson 5 gave students experience in determining time and distance calculations from a piece-wise graph, but neglected to give them the experience in graph interpretation that Trainer B was modeling. Trainer B had focused a reasonable amount of discussion time emphasizing the link between the graphical representation and the teacher's stories, and encouraged the teachers to have similar conversations with their students. This is all missing from Gayle's enactment.

Trainer B also repeatedly modeled the use of a common visual and emphasized its importance, but Gayle did not follow his lead on this at all. Both during the workshop and in her pre-unit log, Gayle claimed to have access to an LCD projector, and yet she did not use one in class. During her interview, she claimed to instead gather the class around one common computer during class discussion, but this did not occur during the three days of observation. This limited the ability to focus class discussions on either the simulation or the graphical representation of the motion.

8.2.2 Analysis

8.2.2.1 How distinctive features played a role

Of course, it is impossible to isolate exactly what led to Gayle's apparent success. However, observations indicate that Gayle exposed her students to the main ideas of the curriculum, along with some other important mathematics. Furthermore, certain of her distinctive features might have played a role.

The extra time Gayle allotted to the early lessons of the unit, plus her coverage of lesson 10 (skipped by many teachers and only skimmed by Carly) may have been a factor in her outstanding M1 gains, but despite emphasis on the M1 lessons and limitations in her approach, her M2 gains were respectable as well. Her daily organization of time may have been a factor in this overall success. Giving students a great deal of time to work independently gave students hands-on time with both the software and the paper-and-pencil work, and also may have been a factor in the class managing to complete so many of the activities in the unit.

Adherence to the curriculum may also be an important attribute. Certainly, students cannot learn what they are not exposed to, so completing all unit lessons provided students with important exposure to the unit's concepts and ideas.

Gayle's method of working through the material activity by activity, rather than trying to fit lessons to the length of a class period as Marilyn did, may have helped her adhere to the curriculum. This approach avoided arbitrary stretching or condensing lessons to fit the time allotted. This may be important in a scale up project; out of seven case-study classrooms, there were six very different daily time allotments: 45, 50, 55, 63, 75 and 80 (Carly's 80-minutes were divided into two daily 40-minute classes).

Gayle's lesson 5 enactment, while having some notable limitations, also lends insight into other possible factors to her reasonable success in M2 gains. Student stories did include details based on the shape of the graph (character was moving fast, slow, stopped, backwards), which is the major "big idea" of the lesson. Gayle's emphasis on the distance and time parameters gave students repeated opportunity to read time and distance information off a piece-wise graph, and she was explicit in her individual interactions with students on how to determine these parameters from the graph (albeit procedurally). This repetition may be important, at least for some students. Additionally, having a small class gave Gayle time to reach every student who needed guidance.

Gayle's adherence to the curriculum also may have played a role in student's deepening understanding of directed motion. Some students may have been confused after the Wendella3 activity (recall some student stories read aloud did not accurately describe the last portion of the graph), but the repetition incurred by completing the Wendella4 and Wendella5 activities may have helped students make better connections between graph and motion, as they wrote stories in which Wendella the dog traveled both forward and backwards several times. Thus, not only exposing students to every lesson, but actually completing all or at least most of the activities, may have made a difference.

Furthermore, although Gayle's behavior sometimes limited how much the software was required to be used, it was always available and Gayle provided ample time for independent work. In fact, video observations caught certain students interacting with the software more than others. Because students were not the focus of this study, data on individual student use of the software is limited. However, it is interesting to note that two of Gayle's nine students had high M2 gains and low M1 gains, with net results (overall gain) above the class average. One of these students had the lowest pre-test score of the class (a raw score of 2), while the other started above the class average. Both had M2 gains more than a standard deviation above the class average and well above the treatment average, and they tied for the lowest M1 gains in the class. The study did not link these scores to specific students, but one is left to wonder if these two students, perhaps working together, used the software on their own more productively than they were required to, and perhaps put their attention and focus on the workbook and software rather than on teacher instructions and suggestions.

8.2.2.2 How training played a role

It appears Gayle picked up strongly on *some* of what was said and stressed in the training. This is to be expected; not everything will be salient to each teacher. But it is interesting to consider the types of things Gayle retained versus what she omitted from her training in her enactment of the materials. Gayle's success is predominantly in M1 skills, which are familiar to her and can be taught procedurally. Her focus in lesson 5 was the basic connection between speed and the steepness of the line and the calculation of time and distance in a piecewise graph. These are M2 level skills, but ones that could be, and were, taught in a procedural manner.

The training itself may have led to some of Gayle's limitations. Although there were only four participating teachers in Gayle's workshop, each teacher worked alone, and Gayle was almost entirely quiet during workshop whole group discussions. Trainer B did nothing to pull her out, or to question her specifically to assess her understanding. Specifically concerning Lesson 5, it has been noted that Trainer B repeatedly emphasized making connections between the Lesson 5 stories and corresponding graphs, but never modeled a simple trace-back between a story and its graph, other than one example that traced back a translation. It is possible that translations were less familiar to Gayle than Trainer B assumed. Considering Gayle's apparently low MKT, and the fact that she was most often a passive participant in the training discussions, perhaps it is not surprising that her approach to the materials did not include explicit references back to the graphical representation. Perhaps she found Trainer B's examples confusing or insufficient and thus intentionally avoided the issues in the classroom. Or, just as likely, without a clear model of what was expected, what this researcher interpreted as a clear emphasis on graph-to-story and story-to-graph connections was simply not interpreted as such by Gayle.

Furthermore, although Trainer B did not interfere while the participants worked on the materials, independent work time was limited compared to the workshops in the other regions because Trainer B frequently discussed topics only loosely tied to the topic at hand. Just as limited time and limited interaction with others may affect student performance, limited time and interaction may have affected Gayle's understanding of the material and the power of the software.

Still, the workshop training and planning day provided Gayle with the basic tools to enact the materials with reasonable success: helping her allot sufficient time, and making her familiar and comfortable with the software and big ideas of the unit. Certainly, from Trainer B's interview it is clear he would have intervened had Gayle's workbook answers been incorrect. Thus her understanding of the material was perhaps not deep but adequate.

8.2.2.3 Implications

It appears Gayle may have privileged certain aspects of the curriculum and materials over other aspects, possibly resulting in her class learning as much but *different* things than other classes. This is reminiscent of the study discussed in the literature review (Kendal & Stacey, 2001) in which three teachers enacted a technology-enhanced curriculum they had jointly created, but each gave priority to different conceptual tasks. In the Kendal study, student test results suggested that each class was successful but had acquired different conceptual understandings and a different set of competencies. It may be that such variation is inevitable in a technology-rich environment, especially in the context of scale-up.

These observations may also give insight into Gayle's particular strengths as a teacher. Recall from the literature Hill and colleague's case-study of Rebecca, a teacher who ranked last on the study's MKT assessment and yet scored better than some of the teachers in certain components of what the study termed Math Quality of Instruction (Hill et al., 2008). Rebecca was described as "largely focused on the mechanics of procedures without corresponding explanation and sprinkled with errors" but, the Hill study concludes, Rebecca's limitations and errors tend to be not-so-damaging. Gayle's case may be similar. Perhaps Gayle gleaned from the workshop what resonated within the constraints of her understanding, and enacted the materials within a comfort-zone of teaching that was effective for her and her class. In other words, she focused on material she knew how to teach. There is no need to diminish this success.

This in turn has implications for training in the context of scale-up, in that Gayle's approach was perhaps limited in certain ways, yet quite respectable overall. Quality curriculum, adequate time allotted for intervention enactment, and training that allowed Gayle to teach to her strengths rather than force a stringent level of fidelity, may have led to an unexpected type of successful outcome.

8.3 Training – Comparing Region A and Region B

It is helpful to contrast the experiences in Region A and Region B for several reasons. Some of these differences may have affected Marilyn and Gayle's approach in terms of the critical features of time and material. On the other hand, other regional differences seem to have had less impact on the implementations of these two particular teachers. It is important to consider why this might be true.

Trainer A and Trainer B had very different approaches to the issues of time and material. **Table 25** summarizes timing issues in both classroom and training enactments:

Table 25: Time and Training

TOT: Time limits are ambitious	**Marilyn (Region A)**	**Gayle (Region B)**
Classroom	Low-range	Mid-range
Training	Did not emphasize timing considerations	Discussed timing considerations

Timing needs were discussed at length in the Region B (Gayle's) training, while this was not a substantial topic in Region A. As it turned out, Marilyn's lesson plans were actually quite similar to Gayle's in terms of time for each lesson, but Gayle extended whereas Marilyn shortened the actual time in class. It is not clear if more reflection on timing considerations, as enacted in Region B training, may have made Marilyn more committed to devoting adequate time to the unit.

While Marilyn's and Gayle's planned time allotments per lesson were similar, the time in Marilyn's lesson plans included extensions such as using CBR's and bringing in road maps to map out a road rally, whereas Gayle allotted a similar amount of time to simply work on the workbook activities.

This in fact exemplifies another interesting contrast between the Region A and Region B training experiences. Region A included a recommendation to skip lesson 6, and also often suggested extensions and creative ways to enact the materials, and Marilyn picked up on some of these suggestions. Region B, on the other hand, focused on how to make the SimCalc materials work as written, rather than suggesting creative alterations and extensions. Issues concerning material coverage are summarized below in **Table 26**.

Table 26: Material and Training

TOT: Accidentally skipped a discussion on what material was essential and what could be safely omitted.	**Marilyn (Region A)**	**Gayle (Region B)**
Classroom	Skipped more than anyone else (including lesson 6) Added “extras”	Only skipped one page of workbook No “extras”
Training	Recommended skipping Lesson 6 Recommended extensions. No discussion of what elements of unit were essential	Did not recommend extensions or omissions No discussion of what elements of unit were essential.

The following two tables summarize Marilyn’s and Gayle’s enactments and training experiences with respect to class organization and level of directive teaching:

Table 27: Class Organization and Training

	Marilyn (Region A)	**Gayle (Region B)**
Classroom	3% review 49% intro 44% student work 5% follow-up	0% review 15% intro 71% student work 14% follow-up
Training	Big Ideas Short Intro's Extended Follow-ups	Modeled autonomy "freedom to learn the way they learn"

Table 28: Directive Teaching and Training

	Marilyn (Region A)	**Gayle (Region B)**
Classroom	"Walked" students through material Answers on projected overhead	Provided instructions, formulas & evaluations that often circumvented use of software and graphical representations.
Training	Did not model or recommend above behaviors Modeled appropriate teacher questioning techniques.	Did not model or recommend above behaviors. Emphasized graphical interpretation and use of common visual of the software

The above summaries reflect another interesting contrast between the two regions, involving trainer modeling. Trainer A frequently modeled appropriate teacher practices, including introductions and follow-up discussions, while Trainer B thought that was unnecessary beyond the first couple of lessons. The opposite was true with respect to using the software. Trainer B frequently focused the teachers on the software, using an LCD projector for whole group discussions, and repeatedly emphasized that a projected image of the software was crucial for its dynamic capabilities, even offering to provide a projector to anyone who needed it. On the other hand, Trainer A simply used overhead slides as a common visual, never focusing the teachers on the software during whole group discussions.

In the case of Marilyn and Gayle, these aspects of training did not appear to carry through: Marilyn did not teach as Trainer A modeled, and Gayle did not focus on the software as did Trainer B. Although Marilyn expressed in her interview that she valued the questioning techniques that Trainer A modeled, her own questioning of students was very leading, and Marilyn often answered the question herself. And despite Trainer B's emphasis on the software, Gayle did not check out a school projector as she claimed she would, nor did she gather her small class around one computer screen during the three days of observation, as she claimed was her typical practice for the unit.

These two aspects of the training, modeling teacher practices and modeling discussions related to the software, are in fact aspects of pedagogy. It might be that teacher's experience and MKT may be the more influential factors than short-term training for these particular aspects of the final enactments. Considering the other case-study teachers further justifies this possibility. For instance, Wendy, a Region A teacher with a 4^{th} quartile MKT score and high school teaching experience, was observed to enact Trainer A's modeled questioning techniques to a more appropriate degree than Marilyn.

But Wendy also made extensive use of a common visual of the software, although not modeled in her workshop. At the same time Sharon, a Region B teacher with a 3rd quartile MKT score and experience teaching through the level of Calculus, did use a projector as Trainer B modeled, as well as focusing students on the motion and graphical representations on their computer screens to a greater extent than did Gayle. An argument could also be made that Sharon's questioning techniques were fairly good, although this was not modeled much in her workshop.

The Scaling Up SimCalc project was never focused on pedagogical considerations; the overall study acknowledged from the beginning that a teacher's pedagogy would not change drastically due to a three-day workshop. It is therefore perhaps not surprising that less experienced teachers did not follow the pedagogical examples of the experienced workshop trainers. There are implications, however. While regional trainers may think they are emphasizing these pedagogical features, at least some teachers may be focusing on more surface features instead, perhaps in some cases skewing the trainer's original intentions.

Chapter 9: Conclusions

As discussed in the literature review, the term *robustness* in the context of scaling is defined as "consistency of the innovation's benefits for student learning when deployed consistently to a wide variety of students, teachers, and setting" (Roschelle, Tatar, Shechtman, & Knudsen, 2008). The results of the overall project provide evidence that the combination of software, curriculum, and teacher professional development used in the Scaling Up SimCalc project appears to be robust, in that almost every treatment classroom had higher gain scores than almost every control group classroom.

Gayle's case in particular suggests that the intervention is robust enough that a certain amount of teaching that is a somewhat altered, unintended version of the teacher's training experience will not necessarily result in poor student performance. Also, although not impressive within the treatment sample, student M2 gain scores in both Gayle's and Marilyn's classes were a great deal above the control average, which again might indicate a robustness of the intervention, in that M2 gains are possible even in somewhat poor environments, or even with a procedural emphasis or emphasis on M1 skills.

This robustness is an important finding. Rather than over-specifying training and curriculum materials to avoid enactment variability, perhaps it is possible to design robust technology-rich interventions that can be successful *despite some inevitable teacher and trainer variability.*

The amount and nature of allowable variability, of course, is key. The less successful results in Marilyn's class suggest that the quality of the classroom enactment remains crucial. This may not be surprising but it is rather reassuring; certainly, the teacher's essential role in the classroom cannot be over-ridden.

This sub-study suggests that a wide variety of enactments may be acceptable and successful, as long as 1) the main ideas are presented accurately, and 2) students are given adequate time and 3) students are given a reasonable amount of autonomy with the materials.

It may perhaps be counter-productive to specify standards too far beyond these general points. Although this investigation does not provide sufficient proof, it does provide examples which would argue against an adherence to stringent fidelity criteria for teacher enactments. Some positive things may simply occur naturally, and enforcing scripted "cookie-cutter" enactments might work against this, especially with short term training. For instance, Gayle's enactment did not seem ideal from the perspectives of the developers and research team, and yet her classroom outperformed the other case study classrooms in terms of average gain score. At the same time, some less than optimal things may be unavoidable with only three days of teacher training. Although it might be beneficial if Gayle had enacted a richer version of Lesson 5, perhaps the lesson she provided was reasonable to expect from a teacher with low MKT and limited training. Also, if a strict level of fidelity were somehow enforced, what exactly would that faithful enactment look like? Certainly, there may well be quality in Gayle's enactment that this researcher did not acknowledge while observing. In the same sense, even a more experienced researcher might underestimate the power and utility of some things a teacher does well; similarly, an outside observer could be mistaken on what might be a detrimental aspect of an enactment.

Based on this sub-study and other results from the overall Scaling Up SimCalc project, it appears difficult to predict which teachers are most likely to experience high student learning gains in the classroom. There are many possible factors that may account for this, including limitations of the testing instrument and observational methods. However, it is possible that teachers simply take various approaches, each approach having a wide variety of pros and cons. Combined with the inevitable variability of students and environments, the success of any specific enactment may be simply hard to predict with great certainty. Even if one were able to choose what might be considered a superior approach, enforcing this approach at scale would be difficult, if not impossible. What was *not* observed in this sub-study were teachers teaching outside their comfort-zone or beyond their level of personal understanding. This may be an important point.

While it is difficult to predict high student gains, all but four classrooms in the overall 8th grade study were adequately successful, outperforming over 85% of the control classrooms in terms of student gains. The observations of this sub-study would imply that variety was the norm in these classrooms; the six adequately successful classrooms of this sub-study each enacted the materials in richly different ways, with varying emphasis on workbook, software, concepts, procedures, graph interpretation, class discussions, independent work and group work, etc. Thus it is not only difficult to choose a "best" teaching approach to the materials, it is even difficult to characterize a "faithful implementation" within this context. Many different implementations were successful, and thus it appears there are many effective ways to teach with these materials, each bringing different resources to the fore. The strength of these resources, and the system design which provides multiple opportunities for student feedback (via any combination of student, teacher, software, workbook, and fellow student(s) interaction), may compensate for potential weaknesses in particular enactments. One implication of this is that perhaps training need not dictate a specific mode of enactment but can focus instead on broader goals.

The 3-day training workshop provided teachers familiarity and comfort with the software, the curriculum, and the related mathematics. The subsequent Planning Day provided assistance in developing realistic lesson plans, perhaps most importantly resulting in reasonable time allotments for each lesson. These aspects of training appeared instrumental in successful classroom enactments. Certainly the familiarity with the software and materials is necessary to allow teachers to teach within their comfort-zone. Furthermore, this sub-study supports the premise that adequate time is essential; if so, then developing realistic lessons plans is a key feature of training.

These conclusions thus have implications for practice, both in terms of classroom enactment and most importantly with respect to training. Implications pertain specifically to these SimCalc materials, but may perhaps generalize beyond that as well. The findings suggest the following recommendations: Given a robust technology-rich intervention such as this, short-term training should include 1) ample time for teachers to become familiar and comfortable with the software, curriculum, and related mathematics; 2) explicit information covering the “big ideas” of the materials; 3) time and assistance for teachers to develop realistic lesson plans, with an emphasis on planning sufficient time for each lesson/activity of the intervention; 4) explicit (proper) guidance on what elements and activities are essential and what (if anything) can be safely omitted if time constraints prevail.

Further recommendations are more pedagogical in nature and therefore more susceptible to teacher misinterpretation. Trainers may wish to emphasize that teachers give students ample independent time with the software and materials, but this could be taken to an inappropriate extreme; independent time should be balanced with appropriate introductory and follow-up discussions. Marilyn’s case demonstrates that trainer modeling of such discussions does not necessarily transfer to classroom enactment; furthermore what is appropriate for intro and follow-ups may well depend on both student and teacher abilities. Certainly, teachers could be advised not to work through the materials in a whole class format, but it is not entirely clear how training could best influence a teacher such as Marilyn to effectively offset a tendency for directive teaching.

Trainers need to be aware of the limitations of short term training, and realize that, while they may wish to model effective teacher practices, at least some teachers may focus on surface features and/or interpret suggestions more literally than intended. Modeling effective use of the software may be especially important yet opaque to some teachers; having teachers work in pairs or groups with the software and materials may be helpful but of course will not necessarily compensate for these difficulties.

There are, of course, limitations to this research. As previously noted, the specificity of the context limits its capacity for generalizations. Still, it is possible the insights provided by this work may prove useful to other training and/or scale-up situations. Furthermore, outcomes have been reported based on testing instruments which are not perfect measures of student learning or teacher MKT; no instrument can make such a claim. However, the instruments employed were carefully designed and rigorously validated, providing the best information available that could possibly capture the depth of understanding students might attain, and the MKT teachers might need, when using these materials.

This sub-study also leads to many possibilities for further research. Of course, there is a need to further investigate the identified distinctive features of time, materials, class organization, and level of directive teaching and their influence on student learning, and to further consider and study how these issues could be dealt with in the context of SimCalc teacher training at scale.

Another possible research topic is to look more closely at Lesson Planning. Recall that Trainer A suggested many creative extensions, while Trainer B focused on how to make the SimCalc materials work as written. In Hill and colleague's study of MKT and Mathematical Quality of Instruction, they discuss that teachers are often encouraged to add supplementary materials to their textbook, and that "for most teachers in our sample, using supplemental activities and materials served to lower the quality of the mathematics in instruction" (Hill et al., 2008). This may be true in these circumstances as well. Especially in the case of a train-the-trainer type situation in which the trainer has little or no previous experience with the materials, encouraging teachers to subtract from or supplement the given curriculum may prove ineffective or even counter-productive. Of course, further study would be required to substantiate this premise.

Another topic for further study is to consider if weaker teachers actually take more from training than the stronger teachers. This may be true within the case-study participants. The case-study teachers with stronger MKT – especially Carly, Jackie &

Samuel, and Wendy, enacted the materials in interesting ways, but in most cases the interesting aspects of their enactment did *not* come from the SimCalc training workshop or Planning Day. In contrast, Gayle's enactment of lesson 5, as already described, was a subset of what she experienced in her own training. This can be seen in Marilyn's case as well. Marilyn's focus on creativity for the lesson 5 stories (over a more mathematical focus) appeared to be tied to what she saw in the workshop. Also, as discussed above, Marilyn's lesson plans included extensions that Trainer A had suggested, such as bringing in CBR's and road maps, while Wendy, who attended the same regional workshop, did not plan these extensions. (Wendy's enactment was not only more autonomous, but in at least one instance even influenced the trainer and her workshop colleagues: it was Wendy who suggested that lesson 6 be skipped, which was picked up by the trainer and then followed by Marilyn.) It may be important for trainers to consider which teachers may be taking their suggestions the most seriously, and how these teachers might interpret the suggestions.

Research could also look more closely at students within a classroom similar to Gayle's, with a high focus on M1 skills and/or procedural thinking, to see if there is indeed a difference in gain scores among students who tend to independently focus more on the software versus those that closely follow the teacher's suggestions.

It also would be interesting to use the existing data to examine the results of certain teachers who were rejected as case-study teachers. Based on workshop observations and sometimes trainer input, these teachers were deemed potentially weak and therefore not ideal candidates, and yet some of them had impressive average gain scores. Although there is no observation data on these teachers, so little can be said about class organization or directive teaching, it would be interesting to look at their MKT-scores and daily logs to look for correlations between MKT, time and material, M1 versus M2 gains, and overall class performance.

Finally, it is of course necessary to continue to study the role of professional development as the scaling process continues beyond these first experiences, for both trainers and teachers. Certainly, there is both room and potential for teachers like Marilyn and Gayle to continue to grow and improve as SimCalc teachers. Fostering this growth is an important aspect of scale-up.

However, it may be that there is substantial tension between two of the scaling dimensions described by Coburn: sustainability and shift in reform ownership. Three of the eight teachers observed and interviewed in this sub-study (including Gayle) described how they might mix the SimCalc materials with other materials the following year. Furthermore, in debriefings with teachers after observing them enact the materials, Trainer A's focus was often on creatively expanding and/or supplementing the materials rather than enacting them as written. This brings into question just how effective the materials might be in a significantly modified state, and what professional development would be required for both teachers *and* trainers to ensure successful sustainability of the intervention. Results from the 2nd year 7th-grade study, which had less successful results than the 8th grade and 1st year 7th grade studies, suggest this may in fact be an important issue.

Appendix A: 8th Grade Core Mathematical Constructs

Linear Function as Preparation for Algebra and Calculus

M_1 – Math Addressed Typically in 8th Grade

1) Problem is within **<u>one representation</u>** of **<u>one linear (but not piecewise linear) function</u>**
   A) Categorize the function as:
      i) Linear vs. nonlinear
      ii) Proportional vs. nonproportional
   B) Use a linear representation to find an input or output value within:
      i) *Symbolic expression*. Given an input, find the output (or given an output, find the input)
      ii) *Table*. Given at least two ordered pairs, complete the table
      iii) *Graph*. Given an x, find corresponding y (or given a y, find corresponding x)
      iv) *Narrative description*. Given a verbal description of an input, find an output

2) Problem requires **<u>translation</u>** of **<u>one linear (but not piecewise linear) function</u>** from one representation to another (use and/or interpret *m* and *b* as key characteristics, or use a few points)
   Α) Graph ↔ Table
   Β) Graph ↔ Symbolic
   Χ) Graph ↔ Narrative
   Δ) Table ↔ Symbolic
   Ε) Table ↔ Narrative
   Φ) Symbolic ↔ Narrative

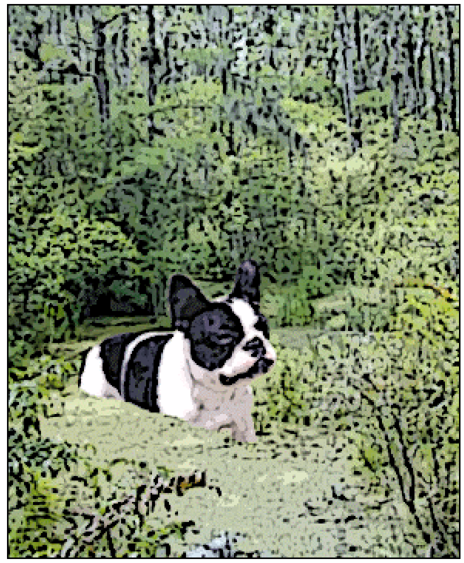
M_2 – Beyond Math Addressed Typically in 8th Grade

3) Problem requires **<u>interpretation</u>** of **<u>two or more functions</u>** that represent change over time, including linear functions or segments of piecewise linear functions.
   A) Compare:
      i) Different segments in a piecewise function
         a) Duration of different segments
         b) Distance traveled represented by different segments
         c) Direction of change (e.g., forwards/backwards, increasing/decreasing) of different segments
         d) Rate of change (e.g., faster/slower) of different segments
      ii) Two or more different linear functions
         a) Time at which two different functions reach a given position
         b) Given a time, the corresponding position in two linear functions
         c) Duration of different functions
         d) Distance traveled represented by two different functions
         e) Direction of change (e.g., forwards/backwards, increasing/decreasing) of two different functions
         f) Rate of change (e.g., faster/slower) of two different functions
   B) Find the average rate over a single multi-rate piecewise linear function

Appendix B: Lesson 5 of unit

Wendella's Journey: Moving At Different Speeds

In our game, *Lost in the Pines*, Wendella the dog makes many journeys through the magical Lost Pines Woods.



On her journeys,

- Wendella moves
  - *Forward slowly* when she is in the swamp.
  - *Forward faster* when she is on the road.
- Wendella *stops* and barks for help when she is in quicksand.

We need many journeys and stories to use in our game. Help us set up the math and tell the story for each journey. Your work is very important. Remember—you are doing the math that will make the game work.

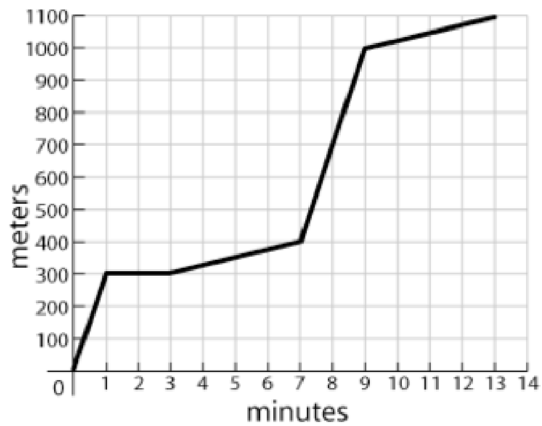
1. Open BUT DO NOT RUN the file for Wendella's first journey, *Wendella1.smw*.

   Using the graph for this journey, predict how Wendella will travel. Finish the story below.

Wendella started out fast on the road. She was happy to be on her journey. Then...

2. Here is a different journey that Wendella took.

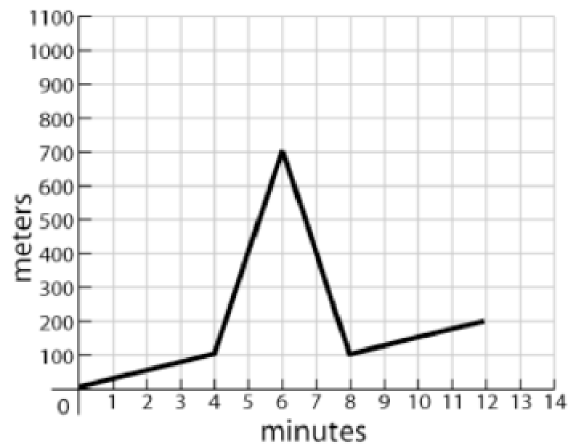
   A. Mark on the graph below, show when Wendella was in the swamp, in the quicksand, and on the road. Mark the times on the minutes axis.



   B. For each line segment in the graph above, find the number of minutes Wendella traveled, the number of meters she traveled, and her speed. You can make a table to keep it all organized.

   C. Choose one line segment in the graph—not the first one—and explain how you found Wendella's speed for that segment.

3. Open the file *Wendella3.smw* for the third journey. The graph is also shown below.



A. Run the file. Wendella does something new here!
   Write a story to go with Wendella's journey.

B. What did Wendella do 6 minutes after starting this journey?

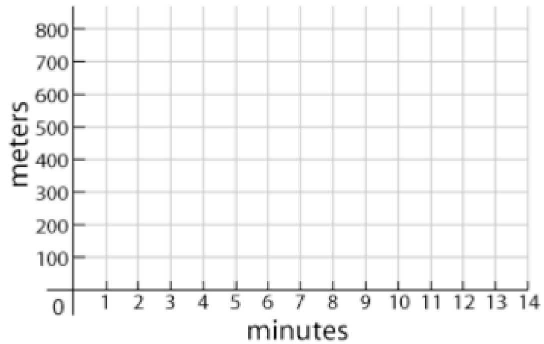
C. How does the graph show this motion?

D. What is her speed between 6 and 8 minutes?

4. Open the file *Wendella4.smw*, and do the following.

   A. Change the graph so that Wendella goes forward and backward at least twice in her journey. Run the graph to make sure it works.

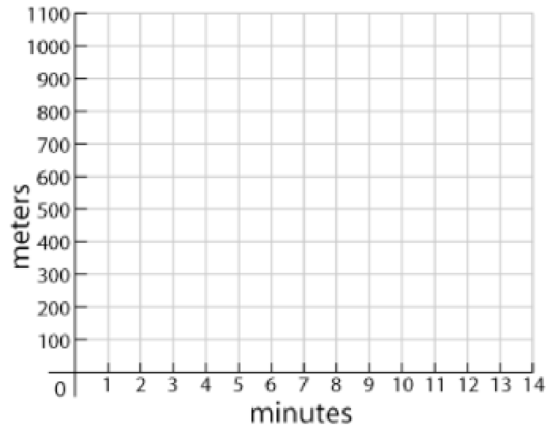
   B. Record your graph on the axes provided.



   C. Write a story to go with this Wendella journey.

   D. One of the programmers doesn't understand what is happening in the graph. Explain how to use the graph to get Wendella to go backward in her journey.

5. We need more journeys and stories. Using *Wendella5.smw*, make your own graph showing Wendella's next journey. Sketch the graph on the axes. Write a story to match your graph.



Story:

Appendix C: Interview Protocol for TOT facilitator

Pre-workshop protocol:

- Please talk with me briefly about the primary purposes of the TOT Workshop that I will be observing.
    - PROBE: What do you hope the ESCs will gain by participating in this Workshop?
- Is there anything in particular that I should know about the participants who will be attending this session?

What do you see as the Mathematical learning goals of the 8th grade unit you will be introducing to the ESCs?

- Do you plan to make these goals explicit? If so, how?
- What, if any, are the unique features or explicit aspects of SimCalc that play a role in this?

- Are there any pedagogical ideas that you view as especially important to share with the ESCs?
    - How do you plan to make these pedagogical ideas explicit?
    - How does SimCalc play a role in this?
- I'm interested in the part of your Workshop agenda, where you say "Bonnie facilitates workshop leadership discussion, including explicit focus: What MUST happen in workshop (and then) classroom for this to work?" Tell me about this.
    - So, what MUST happen?
    - What do you mean "for this to work"?
        1. How will you assess the effectiveness of what you are doing? In other words, how will you know the ESCs are "getting it", and how will the ESCs know the teachers are "getting it"? Based on what evidence will you draw your conclusions?
        2. Will you use your assessment to modify future work?
- Tell me about "The top 10 list of "can the software do this" questions, presented as a set of challenges for us to solve". Is there a purpose to this beyond just getting to know the software well?
- Tell me about the teacher's guide. You mention in the agenda that you want to discuss "the teacher's guide for teacher learning". How is the guide set up to help teachers learn? Are there any aspects of this that may lead to confusion or misunderstanding? How will you deal with that?

- At one of the SRI phone meetings on Mondays, the group was talking about what types of things I should be looking for in my study. One thing you mentioned was "How do things get negotiated?" Can you tell me more about what you meant? What do you imagine being negotiated between facilitator and workshop participant? Or between teacher and student?
- The following are issues on your the agenda:
  - Issues to discuss (in addition to those the ESC leaders bring up):
    - Helping teachers understand the importance of hands on , minds on for kids.
    - Technology use.
    - Questioning techniques and student explanation.
    - Using the teacher's guide for teacher learning.
    - Modeling pedagogy
    - Best practices from 7th grade research

Is there anything in this list of issues that you would like to say more about?

- What do you suspect will happen at the next level – when the ESCs give workshops to the teachers?
  - What mathematical and pedagogical goals do you think will make it to this level? Why?
  - Do you imagine teachers might adapt and improvise? In what ways? Will you be addressing this in the workshop, and if so, how?
  - What goals do you suspect might get 'lost in translation'? Why?
- Realistically speaking, what do you suspect will happen at the final level – when the teachers teach the replacement unit in their classroom?
  - What mathematical and pedagogical goals do you think will make it to this level? Why?
  - Do you imagine teachers might adapt and improvise? In what ways?
  - What goals do you suspect might get 'lost in translation'? Why?

<u>Post-workshop protocol:</u>

- How do you think today's session went? Would you consider it a success?
- Were there any ways in which the session was different from what you had planned?

- What did today's session tell you about what the participating teachers know, and what they still need to learn about teaching linear functions? How will you adapt in response to this?
- Do you think any of the teachers had an "Ah-ha" moment during today's session? Explain what you think caused this reaction.
- Did *you* have any "Ah-ha" moments during today's session? Explain when they occurred, and what precipitated them.
- Were there unexpected challenges in teaching this workshop? Explain.
- Do you think that this workshop has been a successful learning experience for the ESC trainers?
- Is there anything in particular you would do differently?
- Do you think the trainers understood what you told me about Jim Kaput's basic process? (Show a simulation, predict what would happen next, run the next simulation, explain why your prediction was right or wrong)
- Based on what you saw at the TOT workshop, what aspects of the unit do you expect will be especially successful? What aspects do you expect may end up being problematic? Please discuss both mathematical and pedagogical goals.
- I'm going to mention specific math ideas, and for each one, I'd like you to answer 2 questions:

    1. How do you think teaching this concept with these materials may be different from the way it's usually taught?
    2. How might that impact the way students learn these ideas?

        - Rate
        - Speed/time/distance
        - Linear function
        - Thinking with graphs, or using graphs as a thinking tool
        - Proportionality

Appendix D: Journal questions for ESC trainers during TOT Workshop

<u>Summary Questions</u>

1. What do you think is most important about today's session to remember to share with teachers?
2. What aspects of today's session do you anticipate will be most difficult to productively share with teachers? How do you plan to deal with difficulties? Think about:
    a. What aspects of the program will be most difficult to convince them to do, and how can you convince them?
    b. What aspects might they misunderstand, and how might you clarify?
    c. What technological problems might they have, and how could these be minimized?

Appendix E: Interview Protocol for ESC Trainers

Pre-workshop protocol:

Preliminary Questions:

Prelim Q1: Please talk with me briefly about the primary purposes of the workshop that I will be observing.

> Prelim Q1.1: What do you hope the teachers will gain by participating in this Workshop?

Prelim Q2: Tell me a little about your background as it relates to this Workshop.

> Prelim Q2.1: What experience do you have, beyond the TOT Workshop led by Jennifer and Bonnie in May, that you believe will help you facilitate this session well?
>
> Prelim Q2.2 Did you sit in on any of the 7th grade workshops that Jennifer facilitated last summer? If so, did that experience help you prepare for this workshop? In what ways?

Prelim Q3: Is there anything in particular that I should know about the participants who will be attending this session?

Math goals:

Math Q1: What do you see as the Mathematical learning goals of the 8th grade unit you will be introducing to the teachers?

> Math Q1.1: How do you plan to make these goals explicit?
>
> Math Q1.2: How does the SimCalc Mathworlds software play a role in this?
>
> Math Q1.3: How does this approach differ from the usual way in which these concepts are taught?

Pedagogical goals:

Pedagogy Q1: Are there any pedagogical ideas that you view as especially important to share with the teachers?

> Pedagogy Q1.1: How do you plan to make these pedagogical ideas explicit?
>
> Pedagogy Q1.2: How does SimCalc play a role in this?

The software:

SimCalc Q1: Is there anything in particular about the SimCalc Mathworlds software that you intend to emphasize to your teachers? Why?

Teacher's guide:

TG1: How do you intend to use the teacher's guide during your workshop?

TG2: How will you encourage the teachers to use it in the classroom?

What MUST happen?:

Must Q1: In your opinion, what must happen during this workshop, and then again in the teacher's classrooms, for this SimCalc unit "to work".

Must Q1.1: What does it mean to you for the project "to work"?

Adaptations:

Adapt Q1: Are you presenting the materials to the teachers differently than Jennifer presented them to you? Why?

Adapt Q2: Are you adapting the materials in any other way? Why?

Issues from TOT:

TOT Issues Q1: The following were listed as "Issues to discuss" at the end of the TOT agenda. What can you say about these issues as they pertain to the workshop you will facilitate?

- Helping teachers understand the importance of hands-on, minds on for kids.
- Technology use.
- Questioning techniques and student explanation.
- Modeling pedagogy

Workshop preparation:

Prep Q1: Do you think the TOT workshop in May prepared you well to facilitate this workshop? How does it compare to other TOT trainings that you've participated in?

Prep Q2: Can you compare the way you have prepared for this workshop with other workshops you have facilitated? Was it easier, harder, different in some other way? Did it require more or less preparation than a typical workshop for which you attended TOT training first? Explain.

Anticipating difficulties:

Difficulties Q1: What particular issues do you expect will arise for teachers who typically introduce these mathematical concepts in a different way?

Difficulties Q2: Will their practice or pedagogical beliefs need to change/adapt in a certain way? Explain.

Difficulties Q3: How will you address these issues in the workshop?

Predicting outcomes:

Outcomes Q1: What do you expect will happen at the final level – when the teachers teach the replacement unit in their classroom?

Outcomes Q1.1:Which goals of this unit do you expect teachers are most likely to remember and embrace? Please talk about mathematical and pedagogical goals.

Outcomes Q1.2: Do you imagine teachers might adapt and improvise? In what ways?

Outcomes Q1.3: What goals do you expect might get 'lost in translation'? Why?

Post-workshop Protocol:

Preliminary Questions:

[I hope to question the trainer soon after the end of the workshop (at the end of the 3rd workshop day, if possible). I hope these first questions will capture ideas that are foremost in their mind]:

Prelim Q1: How do you think the workshop went? Would you consider it a success?

Prelim Q2: Is there anything about this workshop experience that strikes you as especially important, something that's especially on your mind that you'd like to share?

Prelim Q3: Can you think of a specific time during the workshop when the participants were excited about what they were doing?

Prelim Q4: Can you think of anything that happened during the workshop that surprised you?

- o Did you find yourself modifying your plans for the workshop as you went along? In what ways?
    - o Probe: Could you give me a specific instance when you did something different than planned?
- Were there unexpected challenges in teaching this workshop? Explain. Do you think these challenges could have been avoided, or anticipated?
- Were there any other ways in which the workshop ended up being different from what you had expected or planned?

Math goals:

Math Q1: Were there specific mathematical ideas that you especially tried to target during the workshop? What were they?

Math Q1.1: How did you emphasize them?

Why did you target these ideas in particular?

Math Q1.2: How did the SimCalc Mathworlds software play a role?

- Do you think any of the teachers had an "Ah-ha" moment during the workshop? Explain what you think caused this reaction.
- Did *you* have any "Ah-ha" moments during the workshop? Explain when they occurred, and what precipitated them.

Pedagogy:

Pedagogy Q1: Were there specific pedagogical ideas that you especially tried to target during the workshop? What were they?

Pedagogy Q1.1: How did you emphasize them?

- Why did you target these ideas in particular?

Pedagogy Q1.2**:** How did SimCalc Mathworlds play a role?

[Now, checking on the link between the TOT workshop and this one (which should flow from the pedagogy question, I hope)]:

- At the TOT workshop, many trainers (including you?) emphasized the importance of allowing students to make predictions and express ideas. What did you build into this workshop to encourage that? Do you think it was successful? How did the SimCalc Mathworlds software help?
- During the TOT workshop, many of the trainers also emphasized the importance of linking representations. What did you build into this workshop to encourage that? Do you think it was successful? How did the SimCalc Mathworlds software help?

The software:

SimCalc Q1**:** Were there specific aspects of the SimCalc software that you emphasized during the workshop? What were they? How did you emphasize them? Why did you emphasize these aspects in particular?

Teacher's guide:

TG1: Did you use the teacher's guide during your workshop?

TG2: How did you encourage the teachers to use the teacher's guide in the classroom?

Considering 'affect':

[These 3 questions concern 'emotional times' during the workshop. I'm hoping it works well to ask them consecutively]:

- Can you give me a specific instance when you noticed that participants were confused or frustrated during the workshop? How did you deal with this?
- (Ask if it wasn't answered well when asked earlier): Can you think of a specific instance when the participants were excited about what they were doing? How did you react to this?
- Do you think there was a 'pivotal moment' during the workshop? (If necessary, elaborate: a pivotal moment when all the ideas seemed to 'come together' for the participants, or when the participants went from feeling uncertain to feeling confident, etc.)

What MUST happen:

Must Q1: We talked in the pre-workshop interview about what MUST happen during this workshop, and then again in the teacher's classroom, for this unit 'to work'. Do you think that what MUST happen actually happened in the workshop? And now, what must happen in the teacher's classrooms?

Must Q1.1: Can you give me some insight into what it means to you for this unit NOT to work?

Issues from TOT:

TOT Issues Q1: Once again, I want to remind you of the "Issues to discuss" that were listed at the end of the TOT agenda. What can you say about these issues as they pertain to the workshop you just facilitated?

- Helping teachers understand the importance of hands-on, minds on for kids.
- Technology use.
- Questioning techniques and student explanation.
- Modeling pedagogy

Being more specific on Math goals:

I'm going to mention specific math ideas, and for each one, I'd like you to answer 2 questions:

1. How do you think teaching this concept with these materials may be different from the way it's usually taught?

2. How might that impact the way students learn these ideas?

- Rate
- Speed/time/distance
- Linear function
- Thinking with graphs, or using graphs as a thinking tool
- Proportionality

Assessment:

What did the workshop tell you about what the participating teachers know, and what they could still learn, about teaching linear functions? Did any of this surprise you?

Difficulties Q1: What particular difficulties or issues did you see arise for the teachers during the workshop?

Difficulties Q3: How did you address these issues in the workshop?

Difficulties Q2: Did you see evidence that the teachers recognized that their practice or pedagogical beliefs needed to change/adapt? Explain. Did the teachers seem willing to make these changes? What makes you think so?

We've been discussing your assessment of the participating teachers, what they know, what they're having trouble with, etc. If you were to repeat this workshop, how would you adapt in response to this assessment?

Predicting outcomes:

Outcomes Q1: Based on what you saw in the workshop, how do you expect the teachers will enact these ideas with their students?

> Outcomes Q1.1: What aspects of the unit do you expect will be especially successful? What aspects do you expect may end up being problematic? Please discuss both mathematical and pedagogical goals.
>
> Outcomes Q1.2: Based on what you saw during the workshop, do you expect teachers might adapt and improvise with the materials? In what ways?
>
> Outcomes Q1.3: Again, based on what you saw, which goals do you expect might get 'lost in translation'? Why?

Workshop preparation:

Prep Q1: Now that you've completed this workshop, do you think the TOT training prepared you well? Why? Can you think of ways it could have prepared you better?

Prep Q2**:** Can you compare this workshop with other workshops you've facilitated, for which you attended TOT training first (did it go more smoothly, less smoothly, seemed more successful, less successful)? Is there anything that, in hindsight, you wish you had done before the workshop to prepare? Why?

Wrap up:

Is there anything else about this workshop experience you'd like to share?

How would you feel if you were asked to facilitate this workshop again?

Appendix F: Teacher journal questions from regional workshops

Name:___________________________ **Date:** _________________

Summary Questions for teachers

1. Think about the key features of today's session:
    a. What specific mathematical ideas/concepts were addressed?

    b. Are there any specific features or activities of the SimCalc Mathworlds software that you want to be sure to emphasize to help your students grasp these concepts? How do you expect these features/activities to be helpful?

    c. What pedagogical ideas or teaching methods from today's session do you plan to incorporate when teaching this unit? Why?

2. Do you anticipate any problems in using these ideas/features in the classroom? If yes, explain. What might you do to deal with these difficulties?

3. Did you have any "Ah-hah" moments during today's session, moments when something suddenly became clear to you? Explain.

Appendix G: Interview Protocol for teachers

Note: The following is a revised protocol from the original. Teacher interview questions changed and evolved as I spoke to more teachers and became more experienced. Also, some teachers provided more interview time than others, so interview protocols did vary.

Pre-Observation Questions

PD Questions:

1. You remember me from the SimCalc Workshop you attended over the summer. What stands out for you about the Workshop?
    a. How has it helped you teach the unit?
2. [Asked when appropriate]: I missed your one-day Planning day, so I'd like to know a little bit about that. What can you tell me about it?
    a. What did you do?
    b. What did you talk about?
    c. How did you find it helpful?

Teaching the unit so far:

3. How is the unit going so far?
    a. How do you find teaching it?
    b. What aspects of the unit have gone well?
        a. Why do you think that is?
        b. Please give me a specific example
    c. What aspects are you having difficulty with?
        a. Why do you think that is?
        b. Please give me a specific example
4. How do the students seem to be responding to the unit?
    a. What do you think I should know about their background?
        i. If some students have special needs, please tell me more about these needs and which students this affects.

Previous experience with the materials:

5. Did you try this unit out on another class?
    a. If so, what did you learn from this experience?
    b. How has this impacted your experiences with this current class?
6. Do you know anyone who has already started or finished this unit?
    a. What advice did he or she give you?
    b. Tell me about any experiences you've had using some of this advice.
    c. Tell me about any other plans you have to use any of this advice.

7. Is there anything else about the unit in general that you'd like to share with me?

I will try to ask this final question each day before I observe (this is not always possible):

8. What do you anticipate doing in class on the day(s) I'll be observing?
    a. What do you want students to get out of this activity?
    b. What's the main Math point you want to get across?
        i. So the Math purpose of the day is …
        ii. How do you see the SimCalc/Mathworlds software helping to achieve what you want to achieve today?
        iii. How do you see today building on yesterday's learning?
    c. Tell me about your teaching strategies for the day.
        i. If you have a 'general strategy', can you walk me through it?
            a. Do you have something in your mind, sort of a list of things you want to do when you teach?
        ii. Will the students be working in pairs or groups?
            a. Tell me about how you group the students.
                a. What criteria do you use to create the pairs/groups?
                b. How often do the groups change?
                c. Is this typical for your teaching style, or specific to the unit? If specific, why?
        iii. If you had written these materials, how would you change today's lesson?
            a. Did you incorporate these changes into your plans for today? If not, why not?
            b. (If no changes): So, do you plan to follow the materials then, without skipping or modifying anything?
        iv. Are you planning it the way it was intended?
9. Is there anything else you'd like to share with me?

<u>Post Observation questions</u>

If I can, I will ask the following questions at the end of each day's observations:

10. How do you think today's lesson went?
11. What big Mathematical ideas came out of today's class session?
12. How will you continue with these ideas tomorrow (or next class session)?
    a. So, what do you see as the link between these ideas and tomorrow's lesson?
13. What did you see the students doing with the software today?
    a. How do you see that affecting their learning?
14. What did *you* do today that you found especially effective?
    a. Tell me about it (or an instance of it).

    b. What makes you believe it was especially effective?

15. What did today's session tell you about what the students know, and what they still need to learn, about today's topic?
16. I noticed (*state what was noticed)*…. Does any of that seem related or connected to what you learned at the workshop over the summer?

OK, let's talk about the lesson in terms of what was planned:

17. In what ways was the lesson different from what you had planned?
18. Do you think the lesson went the way it was intended?
    a. What does that mean to you?
    b. How did you come to your conclusion?
19. What would you change about today's session if you could?

Optimally, these last questions will be asked after my observations are complete:

1. I see you're using this unit as a replacement for ________________.
    a. Did you teach 8th grade using those materials last year?
    b. Can you compare the 2 approaches?
        i. How do you think student learning will be affected, or has been affected, by this change in curriculum materials?
2. What, if any, lesson materials have you intentionally modified or left out?
    a. (If none), ask: So, so far you've done every activity in the workbook?
    b. (If some left out): Why did you decide to modify/skip those materials?
    c. Overall, do you think you are implementing this unit the way it was intended?
        i. What does this question mean to you?
        ii. How did you come to your conclusion?

3. Now, I want you to think about the SimCalc Workshop and the Planning Day that you attended over the summer. What ideas or practices did you pick up from those experiences that you found helpful in teaching this unit?
    a. Tell me about your experiences using these ideas/practices.
    b. What ideas or practices do you remember hearing about that you didn't end up using?
        i. Why didn't you use them?
4. Has this unit affected the way you teach?
    a. In other words, are you teaching this unit differently than you usually teach? If so, in what ways?
    b. Do you think this experience will affect the way you teach other curriculum materials? If so, in what ways?
5. Would you recommend this unit to a colleague?
    a. If so, why?
        i. What advice would you give him or her?

b. If not, why not?

6. Is there anything else you'd like to share with me today?

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