Learning to Teach from Anticipating Lessons through Comics-Based Approximations of Practice

by

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To my dearest father, Te-Yu Chen, who devoted his whole heart to raising me and shaping my life, who dreamt big dreams for me and believed in me.

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ABSTRACT

Teaching is complex and relational work that involves teacher's interactions with individual or multiple students around the subject matter. It has been argued that observation experiences (e.g. field placement or watching video clips) are not sufficient to help prospective teachers to develop knowledge of teaching. This study aims to identify, examine, and illustrate the ways in which comics-based representations of teaching facilitate prospective teachers' learning to teach. Specifically, the author explored how the use of a technology supported lesson-sketching tool, *Depict*, enabled prospective secondary mathematics teachers to attend to mathematical interactions between teacher and students in instruction when anticipating the development of a lesson.

Drawing resources from Systemic Functional Linguistics, the author examined the ways in which anticipations of classroom interaction about a planned lesson differ when the anticipation was done using the *Depict* tool as compared with talking through the written lesson plan. Using case study methodology, the study investigated the aspects of the teaching work prospective teachers attended to when engaged in depicting a lesson, and observed the ways in which prospective teachers employed the graphic resources to support their lesson depiction.

The results reveal that prospective teachers using *Depict* tool to create comics-based lesson slideshows immersed themselves in classroom settings and demonstrated their capacity to incorporate detailed teacher instructional actions, student reactions and mathematical tasks in their lessons. The prospective teachers unpacked their planned discrete class activities and attended to the relational nature among teacher, students and mathematics in instruction.

The study indicates that the anticipation of a lesson, through creation of comics-based lesson depiction, could be a learning opportunity that approximates the interactive nature of teaching practice. The study suggests that comics-based representations of teaching can be seen as semiotic resources that mediate prospective teachers' generation of teacher-student moment-to-moment class interactions, and facilitate their attention to instructional issues they have not previously been aware of. The study also implies that in order to engage prospective teachers in learning to do the work of teaching, teacher educators should consider directing prospective teachers' attention to issues of temporality, multimodality and multivocality in instruction.

CHAPTER 1
INTRODUCTION

There is widespread agreement that teaching is complex work that requires special kinds of knowledge. Learning the work of teaching and thus being able to teach competently is challenging. Cohen and colleagues note that teaching does not merely concern teachers' actions. Instruction is an interactive process involving interactions between teacher, students and content (Cohen, et al., 2003; Lampert, 2001, 2010). The National Council of Teachers of Mathematics (NCTM, 2000) clearly states, "effective teaching requires knowing and understanding mathematics, students as learners, and pedagogical strategies" (p. 17). As teaching is relational work that involves teacher's interactions with individual or multiple students around the subject matter, it is challenging to divide the work of teaching and determine what specific aspects of teaching are most important when training novice teachers.

A common activity in which prospective teachers engage during teacher preparation is to observe the work of teaching. However, it has been argued that observation experiences (e.g. in a field placement or watching video clips) are not sufficient to help prospective teachers to develop their knowledge of teaching (Ball, 1997; Ball & Cohen, 1999; Lampert & Ball, 1998). Hatch & Grossman (2009) also note that novices' learning opportunities are limited even when they are in the field observing more experienced teachers. Prospective teachers have difficulties knowing what aspects to attend to in teaching and how to examine the practice of teaching from the teacher's perspective (Lampert & Ball, 1998; van Es & Sherin, 2002).They have limited knowledge of why a teacher would act or interact with students in certain ways.

Researchers and teacher educators have called for the need to ground teacher learning in practice (Ball & Cohen, 1999; Lampert, 2010; Lampert & Ball, 1998). Situated opportunities should be provided for novices, thus allowing them to learn in and from practice. Grossman and colleagues (2009) report that students of professions often learn through experiences that approximate the actual practices of that profession. Lesson planning could be seen as such an approximation of teaching practice. Developing a lesson plan is to anticipate "how" instructional events might occur in the classroom.

Learning to plan a lesson is a common activity that prospective teachers experience during their teacher preparation program as well as a common real-world activity that teachers do when preparing for teaching. Earlier studies on teacher lesson planning have shown that teachers value lesson plans insofar as they present a structured series of instructional activities to be implemented (Clark & Yinger, 1980; Hill, et al., 1983; McCutcheon, 1980; Yinger, 1979, 1980). This list serves as a "memory-jogger" (McCutcheon, 1980) that reminds teachers what they will need to do, where the activities will be conducted and how long it will take to accomplish each activity. While it is essential to include teaching activities in a lesson plan, it is less common for teachers' lesson plans to incorporate, and for lesson plan formats to request, students' actions or reactions to the planned activities, and the teacher's further interactions with students if the lesson plan does not provide guiding scaffolds. Further, lesson planning has been criticized for its limited opportunity for learning because a lesson plan does not involve practicing interactive aspects of teaching and getting feedback from it (Grossman & McDonald, 2008).

Lesson planning, however, could be seen as an activity that engages teachers in attending to the complexity of the teaching work and as a learning opportunity to approximate teaching practice. Researchers and teacher educators have proposed different approaches to lesson planning that encourage teachers to "zoom in" on a particular aspect of teaching practice. For example, Smith and colleagues suggest a "thinking through a lesson protocol" that invites teachers to focus on assigning mathematical tasks and on students' thought processes (Smith, et al., 2008). The protocol contains scaffolding questions that guide teachers to identify mathematical goals, to hypothesize students' thinking and to anticipate how to lead class discussions. A "lesson play" involves teachers in designing classroom dialogues to practice the communication of the content (Zazkis, et al., 2009). This activity attempts to provide teachers opportunities to practice the verbal interactions with students regarding students' emerging conceptions.

Further, the activity of lesson planning has been suggested as a contextualized process for teachers to experience the practice of teaching (Rosebery, 2005). The lesson planning process allows teachers in the "imagined classroom" (p. 318) to examine their understanding of the subject matter and to specify the learning goals for students. Additionally, the planning process enables teachers to anticipate how the events of a lesson may unfold and to expect what students' responses would be to certain activities and questions. In addition, the lesson planning process engages teachers in projecting possible outcomes of the lesson. Therefore, lesson planning can be seen as a way to approximate teaching practice that teachers can learn from and develop their knowledge for teaching.

Rationale for Designing a Lesson-Sketching Tool

One way of engaging prospective teachers in the "imagined classroom" anticipating a lesson is to help them visualize the teaching events of the lesson. The activity of visualizing teaching events is especially important for novices because they have limited experiences teaching and interacting with students around the content in class. Media artifacts, such as comic books and slideshows, have been developed to represent the work of teaching practice. It has been suggested that these media artifacts allow teachers to project their perceptions of teaching on the representations, and therefore call forth teachers' knowledge for teaching (Herbst & Chazan, 2003, 2006). However, novices are generally considered the audience and consumers of these media representations of teaching (Crespo, et al., 2011). They are rarely given opportunities to produce media-based artifacts to represent their actual or imagined teaching and to learn from such experience.

The purpose of this study is to identify, examine, and illustrate the ways in which the making of comics-based representations of teaching engage prospective teachers in attending to instruction when lesson planning. Specifically, I explore the use of a technology-supported lesson-sketching tool, *Depict* (Herbst & Chieu, 2011), that aims to engage prospective secondary mathematics teachers in attending to the mathematical interactions between teacher and students in instruction. This tool was developed by the ThEMaT (Thought Experiments in Mathematics Teaching) project at the GRIP[1] (Geometry Reasoning and Instructional Practices) research group.

Depict is a software tool that allows users to anticipate and present a lesson via a slide show (Herbst & Chieu, 2011). Building upon the notion that learning occurs when learners interact with a "milieu" and get feedback from it (Brousseau, 1997), *Depict* engages users in anticipating lesson events using cartoon-based characters and classroom settings to represent a lesson. Users are expected to employ various graphic features, such as speech bubbles, facial expressions, and a board content creation tool, to generate moment-to-moment teacher-students verbal and nonverbal communication in class events. This tool also allows users to review how a lesson would unfold and modify the lesson. Through creating, viewing, reviewing and revising the comics-based representation of a lesson, prospective teachers have the opportunity to approximate the teaching practice involving the relational work among teacher, students and content in instruction.

Hypotheses and Research Questions

I hypothesize that the *Depict* tool is a "milieu" (Brousseau, 1997) that prospective teachers interact with (and against). The agent (prospective teacher)

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[1] GRIP (Geometry Reasoning and Instructional Practices) is a research group directed by Patricio G. Herbst. Support for the research reported in this article has been provided in part by the National Science Foundation, through grant ESI-0353285; all opinions expressed are the sole responsibility of the authors and do not represent the views of the Foundation.

acts on this milieu through composing a comics-based lesson slide show and virtually enacting the lesson, and he or she gets feedback from the visualization of the composed lesson. This feedback enables prospective teachers to attend to issues in instruction that they may not have been aware of, such as the mathematical appropriateness of the tasks, possible verbal and non-verbal student reactions, and teacher's instructional explanations. Lesson planning in *Depict,* an activity I hereafter refer as "depicting a lesson", could be considered an approximation of practice, thus supporting prospective teachers learning to teach.

My overarching question asks: *How do rich-media resources facilitate prospective teachers' attention to interactions with students?* The research questions that guide the study are the following:

1. How do anticipations of classroom interaction about a planned lesson differ when done using a multimedia lesson-depicting environment as compared with talking through the written lesson plan?
2. What do prospective teachers attend to in the work of teaching when engaged in depicting a lesson?
    a. What do prospective teachers anticipate regarding teacher involvement in a lesson?
    b. What do prospective teachers anticipate regarding students involvement in a lesson?
    c. What do prospective teachers anticipate regarding mathematical work involved in a lesson?

3. How do prospective teachers employ the graphic resources to support their lesson depiction?

In the following section, I use a framework to explain and illustrate the design of the study, and briefly introduce the analytical approaches that attempt to resolve the research questions.

An Activity Theory Framework for the Study Design

The study aims to identify and examine the ways in which the lesson-sketching tool *Depict* engages secondary mathematics prospective teachers in attending to mathematical interactions between teacher and students in instruction. That is, the prospective teachers use *Depict* to anticipate a lesson involving the teacher and student roles and their interactions around the content. The model of activity in activity theory (Engeström, 1999) could help in explaining the activity and experiences in which the prospective teachers in this study are engaged.

Figure 1 represents the basic model of an activity system (Engeström, 1999). In this model, the *subject* is the individual or groups of actors that engage in the activity. An *object* is the physical or mental product the subject produces. The *outcome* is the learning that transpires through the activity. The *tools*, including instruments or signs, mediate the actions to produce the object.

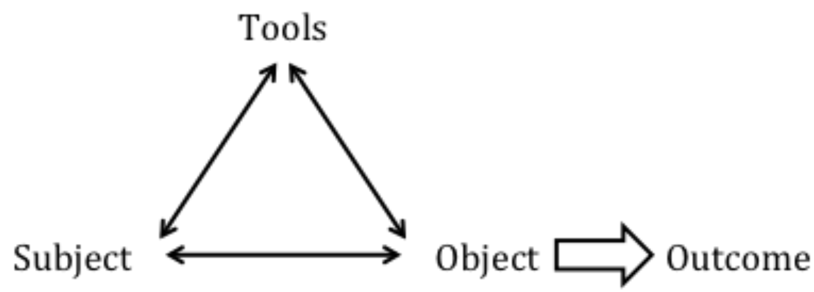

Figure 1. The basic activity system framework.

The study focuses on exploring the affordances of *Depict* and ways in which *Depict* supports prospective teachers to develop deliberate attention toward instruction. The subjects are the participants who are prospective teachers of secondary mathematics. The object is the participants' anticipation of lessons involving teacher and student roles interacting around the content. The tool, *Depict,* is designed and expected to mediate and develop the participant's lesson anticipation. The outcomes are the teacher education knowledge, skills, and dispositions used in the making of lesson slideshows through *Depict* or embedded in the final depictions.

To investigate whether and in what ways the prospective teachers are engaged in using *Depict* to attend to instructional details, the study is designed as follows: I examine and compare the prospective secondary mathematics teachers' lesson plans in written, verbal and visual modes. All participants were grouped in pairs to plan a 15-minute lesson explaining the concept of *slope* in a text-based format (the *written mode* of a lesson plan). They were guided with questions that encouraged them to pay attention to the mathematics work at play and the teacher's and students' actions. Then these pairs of participants were randomly assigned into two groups: the Depict group and Control (Description) group. The Depict group participants used the tool to virtually implement their lessons and create a comics-based slide show to represent the lessons (*visual mode* of lesson). The Lesson Description group participants were asked to elaborate their lessons aloud, with no guiding prompts (*verbal mode* of lesson). By comparing the degrees of detail of planned class events among the different modes, the results of the study attest to the affordances of the *Depict* tool and the impact of visual representations of teaching on prospective teachers' learning to attend to instructional issues.

The mediation tools in the activity system are different in the Control group and the Depict group. In the Control group, the subjects (participants) verbally described how their lessons would unfold based on their lesson plans. The mediation tools involved the lesson plan and a general prompting question: "Could you describe how this lesson would unfold?" The object is the participants' description of a lesson. The outcome is the properties of participants' verbal description of lessons. In the Depict group, the participants were using *Depict* to create lesson slideshows to represent their lessons. The mediation tools included the lesson plans and the graphic features available in the *Depict* environment. The object is the depiction of a lesson. The outcome is the properties of the products generated from participants' depicting of lessons. Figure 2 and Figure 3 illustrate the activity systems involved in the Control and Depict groups.

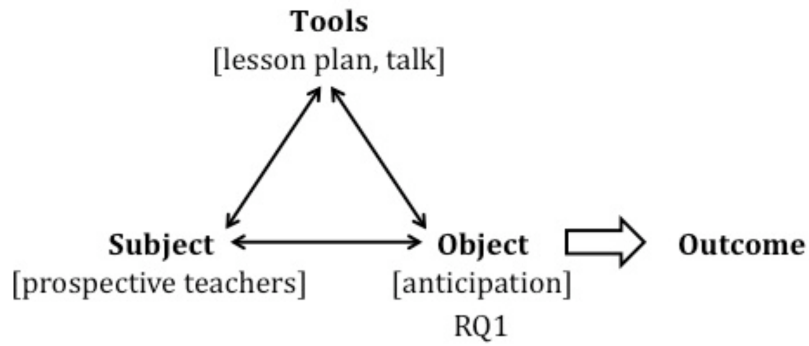

Figure 2. Activity system for the Control group.

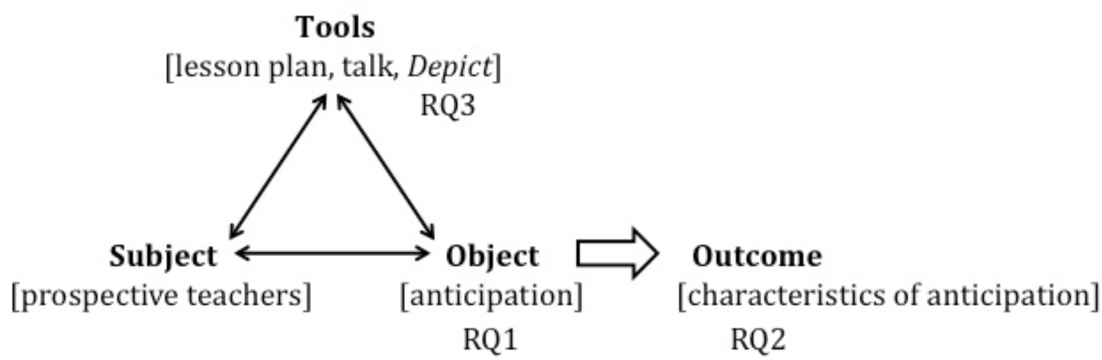

Figure 3. Activity system for the Depict group.

The study is designed to address three questions around the activity systems in the two groups. The first goal is to compare objects – the similarities and differences of lesson anticipations done through two different sets of mediation tools. The second goal is to describe the outcome of the work done by the Depict Group – explore the characteristics of lesson anticipation done with *Depict*. The third goal is to investigate the mediating tool – the prospective teachers' use of *Depict* to produce lesson anticipation.

To answer Research Question One, I compare the differences of class events as anticipated by the two groups: the Depict and Description groups. I draw resources from Systemic Functional Linguistics (Halliday & Matthiessen, 2004) to examine whether and in what ways lesson depiction in a visual mode supports prospective teachers to anticipate lesson events that a verbal mode does not.

In Research Question Two, I seek to examine how lesson depiction develops the mathematics tasks planned in the text format. I conduct a task analysis (Doyle, 1983; Herbst, 2003) to examine the goals, resources and operations involved in tasks to investigate the degrees of detail with which the participants anticipate their lessons. I also identify the instructional issues that the prospective teachers attend to during lesson depiction.

For the final Research Question, I explore how prospective teachers utilized the graphic features in *Depict* to attend to instructional details. I evaluate the use of graphic features and users' behavior (Bailey & Konstan, 2003).

I employ different methodologies to probe the affordances of a technology-supported lesson-sketching tool. The analyses show how this comics-based representation of teaching enables prospective teachers to develop attention to the work of instruction and supports their learning to teach.

Dissertation Overview

The dissertation is presented as follows. Chapter Two presents a framework for the study of teacher learning. I discuss related literature on representations of teaching and lesson planning in teacher learning. I also describe a framework for thinking about mathematics instruction. In Chapter Three, I present the design rationale of the *Depict* tool, and introduce its graphic features. I also discuss the study design and methodologies used in this research. Chapter Four to Six present the results of three pieces of analysis: First, I show the differences of details of planned class events between the Depict and Description groups. Second, I describe how prospective teachers who use *Depict* attend to the complex instructional issues relative to their lesson plans. Third, I present the result of the use of graphic features and user's behavior in *Depict.* In Chapter Seven, I summarize the results and discuss the implications of the study.

CHAPTER 2
REVIEW OF LITERATURE

In this chapter, I first discuss a learning mechanism that forms the base of the design of the learning tool provided in this study. Then, I review the use of representations of teaching in approximating practice. I discuss the notion of lesson planning, identify problems in novice teachers' lesson planning and compare with expert teachers' lesson planning. I then review the learning opportunities afforded through lesson planning, and discuss a situated perspective of planning lessons.

Learning from Interacting with *Milieu*

Learning occurs when the learner acts on a "milieu" and gets feedback from such action. This sequence of actions and feedback from interacting with the milieu forms a "situation" (Brousseau, 1997). When the learner acts on the milieu, the milieu is altered, and provides feedback for the learner. The learner must analyze the situation by gathering information, making judgments, and initiating another move.

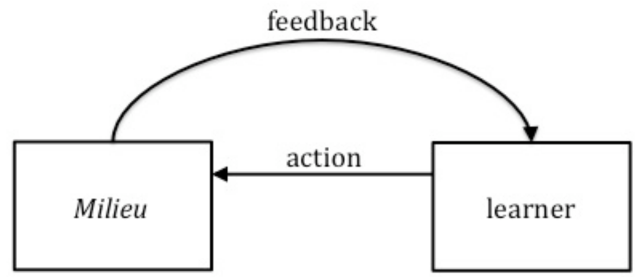

Figure 4. The learning situation.

The notion of learning through interacting with a "milieu" provides a foundation for the design of a lesson-sketching tool proposed in this study. The tool, *Depict,* provides a working space for users to create lesson slides using comics-based features to represent classroom interactions. Users (prospective teachers) first create a piece of class events on the slides. From visualizing partially or wholly completed lesson slides, users get feedback on how the class events might play out. Consequently, users can judge whether to revise the events or proceed to designing the next event. If revisions are deemed necessary, users modify the current representation of the lesson slides. If users decide to proceed to creating new events, they add new elements to the slides.

The tool is intended to form a "*milieu"* that engages prospective teachers in anticipating class events. It is expected that, through the visual display of representation of the lesson and the text involved in the teaching events, prospective teachers will receive feedback on how their lesson would unfold, and are then better able to address the issues and the aspects of teaching that might not have occurred to them, had they planned their lessons through text alone. The interaction with graphic elements in *Depict* is expected to facilitate prospective teachers' learning about teaching with insights on teacher and student interactions around the content.

However, a feedback loop on its own does not necessarily promote learners' awareness of what needs to be learned, due to the influence of the learners' personal prior experience. In the context of learning to teach, feedback may come from the learner's own experience as a student. Learners' knowledge of how classroom interaction proceeds also serves as feedback. The effect of "the apprenticeship of observation" (Lortie, 1975) may guide the prospective teachers to represent lessons that they had previously experienced. Hence, the *milieu* involved in the *Depict* tool can provide prospective teachers opportunities for learning teaching. However, it may also require resources outside the *milieu* to provide prospective teachers immediate feedback on their anticipation of lessons.

Using Representations of Teaching to Approximate the Practice

Various formats of representation of teaching have been adopted in teacher professional development, such as narrative cases and video records of classroom interactions. It has been suggested that these representations of teaching are useful resources to call forth and develop teacher knowledge. With the support of technologies, learners of teaching are provided with tools to interact with representations of teaching, such as conducting analysis, making annotations (Beardsley, et al., 2007; Bryan & Recesso, 2006; van Es & Sherin, 2002) or creating digital notebooks and journals (Davis, et al., 2004; Fishman, 2007; Lampert & Ball, 1998). In the following section, I review technology-supported tools that incorporate representations of teaching and provide a work platform for novice teachers to engage in working with these representations and learning the practice.

Lampert and Ball (1998) call "records of practice" a collection of artifacts about teaching which are developed from one's own teaching, such as teacher journals, teacher and student notebooks, videos, and transcripts. They are resources that are used for studying the authors' own teaching and are open to prospective teachers who wish to study the work of teaching. The learners of teaching are able to create their own "notebooks" to investigate particular issues in teaching by selecting and composing pieces of artifacts from the database. Furthermore, such notebooks serve as common texts that allow other learners of teaching to annotate and comment on the same material.

There have been extensive efforts in developing software tools to support archiving, editing, and annotating video records of teaching, such as *Visibility* (Santagata, et al., 2007), *VAST* (Video Analysis Support Tool; van Es & Sherin, 2002) , *VideoPaper Builder* (Beardsley, et al., 2007), and *VAT* (Video Analysis Tool; Bryan & Recesso, 2006) . These tools commonly provide scaffolds which guide users to reflect on their own teaching or analyze others' teaching (Rich & Hannafin, 2009), for the purpose of "seeing" and learning the complexity of teaching practice (Grossman, et al., 2009). For example, Sherin, van Es and colleagues developed a video annotation tool, *Video Analysis Support Tool* (VAST), that allows teachers to analyze their own or others' teaching through guiding scaffolds (Sherin & van Es, 2005; van Es & Sherin, 2002). The tool aims to develop teachers' capability to notice classroom interactions. The tool guides the users to attend to three particular aspects of instruction: (1) student thinking, (2) teacher's role, and (3) discourse. In their study on effectiveness of using *VAST* to learn to notice (van Es & Sherin, 2002), they found that novices who had access to the tool were able to analyze the class interactions more deliberately than those who did not use the tool. The novices who used the tool were better able to identify noteworthy moments from the videos, provide evidence to support their earlier identification of teaching or learning principles, and interpret student thinking and teacher moves. The authors note that these interpretation skills will inform teachers' decision-making in instruction.

Unlike the tools that engage users in centering learning experience on video records of teaching, KNOW (Knowledge Networks On the Web) is a curriculum-centered tool with support from various forms of representations of practice (Fishman, 2003, 2007). The tool contains resources, such as student work and videos, to support teachers' learning about the curriculum and demonstrate the enactment of that curriculum. The tool also has an online forum that allows users to discuss questions and issues around the curriculum. Moreover, the tool permits users to create personal teaching logs to record their own actual practice of the curriculum. These teaching logs also serve as references for their own or peers' future practice. KNOW integrates classroom-contextualized representations of teaching with the intended curriculum and therefore prepares teachers to improve their practice.

Similar to KNOW, CASES (Curriculum Access System for Elementary Science) was developed to provide "educative curriculum materials" for novice teachers to learn to teach inquiry-oriented science (Davis & Krajcik, 2005; Davis, et al., 2004). The representations of teaching available in the tool are created with emphasis on their educative values. Unit plans play a major part in the tool, containing students' ideas, content information, and instructional foci. It also contains text-based real or hypothetical teaching scenarios that illustrate particular instructional techniques and situations. The tool also provides guiding prompts for reflection and encourages users to keep personal online journals. Additionally, users are invited to go to an online discussion forum to share ideas and get support for teaching. Overall, the representations of teaching provided in the tool serve as reference resources for planning lessons and learning pedagogical strategies. Unlike other tools reviewed, the majority of the representations of teaching in CASES are not collected or generated directly from actual teaching. Rather, they are developed with the intention to demonstrate model instructional ideas. With these representations of practice as educative resources, novices are expected to enrich their knowledge base for teaching, and enculturate themselves in the community of teaching practice.

The technology-supported tools reviewed above share several similar features: (1) These tools contain representations of teaching that portray aspects of practice. The records of practice, in multimedia or in texts, are from three major sources: first, raw materials collected from the act of teaching; second, the contents processed from the raw materials, such as transcripts; third, new materials (e.g.

curricula, unit plans) developed for instructional purposes. (2) These tools provide workspaces that allow learners of teaching to make text-based annotations or journal entries. (3) Learners of teaching are the audience or users of the representations of teaching (Crespo, et al., 2011). Although in some cases, learners have to create their own records of teaching before working with these resources, they are seen as users of these representations when working in the tool. (4) These tools provide contexts in which learners can practice skills (e.g. learning to notice, learning particular instructional techniques) related to teaching in a safe environment, a way to approximate practice, before doing the actual professional work.

Graphic representations of teaching

Graphic representations, such as animations, comic books and slideshows, have been used to extend the use of text-based stories and narrative cases. For example, animated narrative vignettes (ANVs) (Tettegah, 2005) are two-dimensional representations that illustrate particular situations or stories. Learners in school settings (e.g. elementary students) and learners in teacher education settings (e.g. prospective teachers), have constructed animated narrative vignettes to share their own real-life stories and elicit discussions around specific issues (Bailey, et al., 2006; Tettegah, et al., 2007).

Building upon the notion that stories and narrative cases are resources for studying teaching (Carter, 1993; Clandinin & Connelly, 1996; Richardson & Kile, 1999), Herbst, Chazan and colleagues have used forms of comics-based sequential art (McCloud, 1994) to represent hypothetical mathematics teaching scenarios

(Herbst & Chazan, 2006). They propose that comics could be seen as a semiotic resource for creating representations of teaching adopted in teacher education (Herbst & Chieu, 2011).

In the present study, a technology-supported tool is used to allow novice teachers to sketch their lessons using graphic resources to create comics-based slideshows. Unlike other technology-support tools containing collections of records of practice, the tool in this study, called *Depict*, offers comics-based graphic elements that can illustrate virtual classroom interactions. The major element of the *Depict* tool is a canvas that invites users to manipulate the given graphic resources and create lesson slides that represent how their lesson would unfold. Instead of being audiences or users of representations of teaching, novices generate the multimedia artifacts in *Depict* themselves. It is expected that novices will practice their instructional interactions with students and develop deliberate attention to instructional issues prior to their actual teaching practice.

Lesson Planning

Lesson planning is generally defined as what a teacher does that helps to prepare for future action (Hill, et al., 1983; Yinger, 1980). Many previous studies on teacher lesson planning have centered on conceptualizing teachers' decision-making behavior and thinking processes during lesson planning. These researchers have found that when planning a lesson, the content and materials are the main focus that guide teachers in designing the activities of a lesson (Hill, et al., 1983; Peterson, et al., 1978; Yinger, 1986); in other words, teachers spend the majority of their time arranging instructional activities, and these activities, or the topics to be covered, are the major components in structured written plans (Yinger, 1986).

A lesson plan organizes the instructional activities and serves as a framework that guides teachers how to proceed during the instruction. It generally consists of a list of activities, which is seen as a "memory-jogger" (McCutcheon, 1980) that reminds teachers what they will need to do, where the activities will be conducted and how long it will take to accomplish each activity. A lesson plan is also seen as a "script" (Shavelson, 1983) which helps teachers to incorporate the interactive elements of teaching. However, teachers' lesson planning is not necessarily reflected in their written plan (Morine-Dershiner, 1978-79). That is, teachers may conduct "mental-planning" (McCutcheon, 1980) involving mental "lesson images" that are not reflected in the written lesson plans, but which nevertheless influence the actual implementation of lessons (Morine-Dershiner, 1978-79; Schoenfeld, et al., 2000). Teachers may also have an "agenda" in mind, consisting of goals or actions that they intend to implement later in class (Leinhardt, 1993).

Novice teachers' planning

Research which conceptualizes teachers' planning processes has found that when planning, teachers may consider students' learning abilities or interests to a certain extent, but their incorporation of students' thinking and learning into planned class activities is limited. Although teachers place significant emphasis on the content or activities, they do not seem to focus equally on student thinking and potential interaction with students when planning (Peterson, et al., 1978; Roskos & Neuman, 1995). This is especially apparent when teachers are not familiar with their students or have limited knowledge about student learning. For example, in a study about beginning teachers' planning for literacy instruction, Roskos and Neuman (1995) found that the teachers, who were in their first year of kindergarten teaching, spent a significant amount of time in planning activities and preparing classroom settings to carry out the activities. However, their planned activities were not well connected and were neither practical nor appropriate for children. Further, although these teachers tended to imagine how the planned activities would play out in class, these activities were fragmented, rather than integrated. These teachers ended up "just doing activities" (p. 208) without giving substantial thought to how teacher and students would interact around the subject in each activity.

Borko, Livingston, McCaleb, and Mauro (1988) conducted interviews with twelve student teachers, in both elementary and secondary levels with different content areas, about their lesson planning process. Interview questions included how they planned, what they thought about and what influenced the planning. The results showed that all student teachers mentioned planning the overall content and teacher/student activities. Over half of the study participants attended to the goals of lessons, the organization of instructions and curriculum materials. Only one student teacher provided alternative plans for unexpected class events. These student teachers did not attend to students' attributes – such as affect, participation, learning, or behavior – until they taught the lessons.

Comparison between novice and expert teachers

Leinhardt (1993) identified that the agenda is one aspect of teaching that illustrates the differences between expert and novice teachers. Leinhardt defines an agenda as "an operational plan that is concise, focused, and descriptive; the general set of goals and actions in which the teacher intends to engage for the next 40 to 50 minutes" (p. 19). An agenda is also considered to be "the teacher's local mental notepad of the more formal plan" (p. 20).

In that study, teachers were asked to describe their lesson before implementing it: "What are you planning to do today?" Leinhardt found that the novice teacher provided an agenda that could not help her manage the complex instructional situation. She mentioned the artifacts and materials (e.g. paper clips, books, erasers) to be used in the lesson, but did not specify the instructional goals of the lesson. This lack of specific goals would hinder the teacher from adjusting her actions during instruction. Additionally, the agenda included impractical activities that were too long to accomplish in a single lesson, a trait shared with the novice teacher in Roskos and Neuman's study (1995). Furthermore, the teacher did not include the content or topic of the lesson in her agenda.

Unlike the novice teacher's lack of attention to the content and students' involvement in the planned activities, the experienced teachers in Leinhardt's study specified the teacher's and students' actions. For example, one teacher noted how she would make a connection between two representations of the same concept. Similarly, another teacher's agenda included the goal of the lesson and its relationship with the prior lesson. Experienced teachers also predicted students' possible behavior (Leinhardt, 1993).

In their comparison of expert and novice teachers' lesson planning, Borko and Livingston (1989) identified differences and similarities in novice and expert teachers' lesson agendas. In their mental planning, expert teachers attended to details in their instruction. For example, they considered carefully how to introduce a topic or how to best explain a concept so that their students would understand. They also selected a collection of examples or problems for possible use. They determined which specific examples or problems to use depending on their interaction with students during instruction. An expert teacher reported his thinking every morning when planning: He asked himself: "How much time I'm going to spend on this? …How exactly am I going to introduce the line and bar graph? What am I going to have the kids do?" (p. 480) His self-report reveals that in his daily planning, he attended to his instructional moves, such as explaining concepts and designing activities to engage students in learning, and he attended to the time it might take to accomplish a particular activity. In addition, expert teachers in different grade levels focused on different issues in instruction: secondary teachers tended to focus on explanations and presentation of content, while elementary teachers tended to attend to types of instructional activities.

Novice teachers in Borko and Livingston's study were purposefully selected based on their strong mathematics content and pedagogical knowledge. In addition, the data was collected toward the end of their student teaching placement. The above factors may explain why these novice teachers shared certain similar traits with expert teachers when planning. For example, their lesson agendas involved flexibility in timing, pacing, and selection of examples and mathematics problems. Nevertheless, unlike expert teachers, these novices were only able to conduct short-term planning because they considered their content knowledge to be too limited to plan extensively for a longer term. In addition, they experienced difficulty in knowing how to present the content appropriately to students. Further, they noted their inability to identify students' learning difficulties.

Similarly, Livingston and Borko (1990) focusing on review lessons in secondary mathematics classes, found that expert teachers had detailed mental plans that allowed them to conduct their lessons flexibly. They aimed to address students' questions attentively and to give a comprehensive review that highlighted the interrelationship among all major concepts. Additionally, they intended to address students' common misconceptions and errors.

Both novice teachers provided review problems for students to work on and planned to respond students' questions. They also worked on the problems in advance, to prepare for accurate explanations and presentations. However, when actually teaching, their explanations merely guided students in procedural problem solving. They did not address nor integrate mathematical relationships among the concepts or topics. Additionally, in their teaching, they failed to provide comprehensible explanations or examples when responding to unexpected questions from students.

Schoenfeld and colleagues developed a series of studies regarding experienced and novice teachers' lesson planning and teaching (Schoenfeld, et al., 2000; Zimmerlin & Nelson, 2000). Their research is centered around the concept of a "lesson image" – a term borrowed from Morine-Dershiner's (1978-79) work on teacher planning – which they explain as "the teacher's full envisioning, before instruction, of how the lesson will play out in practice" (p. 250).

In their study about a student teacher teaching an Algebra 1 class, Zimmerlin & Nelson (2000) found that although the student teacher had a complex "lesson image" involving a series of activities with associated goals and students' probable responses, the actual classroom interaction did not occur as planned due to a student's unexpected answer, leaving the students confused at the end of class.

A similar study was conducted to investigate an experienced physics teacher's planning and teaching (Schoenfeld, et al., 2000). The teacher designed the lesson and had great familiarity with the materials. When verbally describing his vision of the lesson (the lesson image), he stated the goals of the lesson. Additionally, he anticipated how the students would respond to each of the planned activities, the questions students would raise, and how he would react to students. As a result, the teacher's lesson image was realized accordingly in his lesson. The researchers concluded that the teacher's knowledge in content and pedagogy enabled him to smoothly implement the lesson.

Summary of teachers' lesson planning

Overall, the research reviewed above reveals that teachers – novices or experts –attend to teacher actions in their planning, including ways to introduce, explain or present concepts. They also prepare different problems or examples for possible use (Borko & Livingston, 1989; Livingston & Borko, 1990).

However, novice teachers tend to ambitiously plan activities that are impractical to accomplish due to their failure to consider students' thinking (Leinhardt, 1993; Roskos & Neuman, 1995). In addition, novices do not attend to certain issues in instruction that experts take into account. For example, with regard to teacher's instructional actions, expert teachers tend to make connections and address the relationships among topics (Leinhardt, 2001; Livingston & Borko, 1990) or make a connection between two representations of the same concept (Leinhardt, 2001). Expert teachers also address possible misconceptions or errors (Livingston & Borko, 1990). Regarding student participation, expert teachers attend to student behavior (Leinhardt, 1993), students' answers (Schoenfeld, et al., 2000) or possible questions (Livingston & Borko, 1990; Schoenfeld, et al., 2000). Further, expert teachers anticipate how they might respond to students' questions (Schoenfeld, et al., 2000). Expert teachers are also careful to allot an appropriate amount of time for instructional activities (Borko & Livingston, 1989).

Lesson Planning as a Learning Activity

To engage teachers in attending to the complexity of teaching – especially novices who have limited knowledge of content, pedagogy, students and classroom experiences – researchers and teacher educators have proposed different means and strategies to help teachers in lesson planning. There seems to be agreement that a typical linear or step-by step lesson plan template has limited ability to enable teachers to envision and learn the practice of teaching (John, 2006; Kagan & Tippins, 1992; May, 1986; Zazkis, et al., 2009). Different alternatives proposed for lesson planning tend to guide teachers to "zoom in" on a particular aspect of teaching practice.

Smith and colleagues propose a schema entitled *Thinking Through a Lesson Protocol* (TTLP), aiming to help teachers focus on students' mathematical thinking and implementing mathematical tasks (Hughes, 2006; Smith, et al., 2008). The protocol contains three steps with a series of scaffolding questions that guide teachers to think through a lesson. The first part asks teachers to identify specific goals for the mathematical task. The second part prompts teachers to hypothesize students' thinking and what questions they might ask to advance students' understanding while students work individually or in small groups. The last part leads teachers to think how to orchestrate a class discussion if students have come up with different solutions for the assigned task. This protocol shifts teachers' attention from the teacher's actions to the students' thinking while lesson planning.

Zazkis and colleagues (2009) propose an alternative model of lesson preparation—a "lesson play." A "lesson play" involves teachers in designing classroom dialogue to attend to the communication of the content. This model provides a context for teachers to practice "the interaction with students in general and with students' emerging conceptions in particular" (p.43). By creating classroom teacher-student verbal exchanges, it is claimed that one would attend to the proper use of mathematical language, the explanations of concepts, and students' possible reasoning and thinking. One also has to deal with the development of students' thinking and the unexpected consequences that the teacher might face.

Similar to the *Thinking Through a Lesson Protocol*, a lesson play draws teachers' attention to anticipating different students' thinking and how the teacher's responses can advance students' reasoning. Unlike other lesson planning formats involving a descriptions of activities, a lesson play focuses on the teacher-student encounter moments that might happen in the classroom. In addition, a unique feature afforded in a lesson play is that it requires teachers to anticipate individual students' responses, including naming students and determining which particular student might participate in the discussion. While the lesson play presented by Zazkis *et al.* demonstrates various potential benefits, it is not specified whether and how novices are able to engage in this kind of activity to obtain the benefits discussed above.

Lesson Planning as a Contextualized Experience

Planning allows a person to "visualize the future" and think "in the future tense" (Clark & Yinger, 1987). Lesson planning should involve teachers visualizing what might happen in the lesson. Drawing upon the notion of imagining (Casey, 2000), Rosebery (2005) proposes that teachers be situated in an "imagined classroom" when lesson planning. In the "imagined classroom", teachers anticipate the activities that they will implement, in addition to the possible interactions between the teacher and students.

The phenomenologist Edward Casey explains ways of imagining when making sense of one's experience (Casey, 2000). He identifies three different ways of imagining—imaging, imagining-that, and imagining-how. First, imaging refers to "an imaginative presentation whose content possesses a specifically sensuous—an 'intuitive' or 'imagistic'—form" (p. 41). To image in the context of lesson planning, one would identify what the end product would be, such as the contents to be taught and the goals of a lesson.

Second, "imagining-that" indicates making relationships among the images. For example, one imagines the "state of affairs" that may include "temporal precedence, spatial contiguity, causal connection, and modification or qualification of various kinds" (p. 42). "Imagining–that" in lesson planning may mean that teachers design the sequence of instructional activities. Within each activity, they decide the location in which to implement the activities, time spent on each teaching event, and the arrangement of student group work or individual work.

Third, "imagining-how" is to anticipate "how to do, think, or feel certain things, as well as how to move, behave, or speak in certain ways" (p. 44). To "imagine-how" requires one to be an imaginer as an agent involved in the situations in order to anticipate how an event would occur or how a task would be accomplished. In lesson planning, "imagining-how" indicates anticipating how a teacher interacts with students mathematically, including the teacher's actions (e.g. how to explain a concept, how to represent the subject, how to pose questions, how to respond to students), and students' actions (e.g. what their thought processes might be, what their responses might be). As the aforementioned studies on lesson planning show, teachers do not always "imagine how" when they plan lessons. The anticipation of classroom interactions is often missing in the process of lesson planning.

Building on Casey's notion of imagination, Rosebery (2005) argues that lesson planning is a contextualized process that teachers undertake to experience the practice of teaching:

> ….lesson planning can be a situated, imaginative and lived experience, one in which a teacher calls on her theory of learning and teaching, her knowledge of her students, her knowledge of the subject matter, and her instructional objectives to create a scenario that she can use in situ to respond creatively to her students' spontaneous talk and activity while at the same time keeping her instructional objectives in focus (p. 301).

Rosebery also draws upon the idea of the "lived-in space", proposed by Nemirovsky and colleagues (1998), and states that lesson planning is a lived-in space that is "continually re-created as one acts, explores possibilities, and practices ways of doing things within it". She also sees that lesson planning is "a place into which and from which to project, enact, and evaluate intentions; to explore possibilities; to juxtapose past, present, and future time; and so on" (p. 304).

In her study of a planning session on linear motion by an experienced teacher named Mary, Rosebery described the teacher's thinking as engaged in an "imagined classroom" that allowed her to anticipate what might happen in the coming lesson. During the planning session, Mary first reviewed the videotape from previous lessons, and then thought through possible student reactions to the question she had proposed at the end of the previous lesson.

Three different kinds of teacher thinking emerged from the planning session. First, the teacher was able to specify the learning goal. The main focus for the teacher was to propose different activities by imagining where and how the students might experience them in the sequences of activities. After visualizing how students might encounter the mathematical ideas in the proposed activities and what difficulties students might have, the teacher revised the activities. Hence, the teacher was engaged in her thinking of the lesson in the imagined classroom, and consequently she was able to firmly identify the objectives of the lesson and hypothesize how her students might learn.

Second, the teacher was able to use her understanding of students' mathematical thinking to project possible thinking or responses to the proposed activities. Reviewing the videotape of the previous lesson allowed Mary to interpret and understand her students' thought processes. With this understanding of student thinking, she was able to decide what follow-up activities might enable students to learn. Specifically, she anticipated a particular student's thoughts, confusion, and reactions to the designed activity.

Third, the teacher was able to examine her own understanding of the subject matter. She was in the imagined classroom of her past learning experience, and examined how she came to learn speed, distance and time. By integrating her past and present learning experiences of the subject, she was able to expand this knowledge in order to anticipate and hypothesize how her students might learn the concept.

Compared to the aforementioned studies on the psychological process of lesson planning, the notion of lesson planning proposed by Rosebery is different in that lesson planning is situated within an "imagined classroom". Planning in this context affords teachers opportunities to anticipate a lesson containing detailed scenarios —how the events of the lesson would unfold, how students might think and respond to certain activities and questions, and how the outcomes of the lesson might develop.

Hence, as Rosebery claims, lesson planning in an imagined classroom could be seen as an a priori process for teachers to anticipate the lesson, thus guiding them to anticipate more predictable outcomes. Such a process of anticipation is considered a learning experience for teachers in developing their knowledge of teaching.

However, in Rosebery's study, it is not apparent what resources enable the teacher to anticipate a lesson in the imagined classroom. For prospective teachers who have little teaching experience in real classrooms, it is even more difficult to anticipate a lesson in an imagined classroom. Therefore, to make the lesson planning a learning experience for prospective teachers to develop their knowledge for teaching, it is important to create resources that engage them in thinking and planning the detailed classroom scenarios in an imagined classroom.

Summary

I have identified common problems in novice teachers' lesson planning and instructional issues that expert teachers attend to during lesson planning.

Researchers and teacher educators have proposed scaffolds or tools that support teachers to attend to particular aspects of teaching practice when lesson planning. Lesson planning appears to be a potentially useful experience for learning how to teach. However, it is not clear what kinds of resources engage prospective teachers in learning. Representations of teaching have been extensively employed in teacher learning settings because they allow prospective teachers to practice and learn particular teaching skills. However, teaching is a complex task, involving relationships among the teacher, students and content. The dissertation studies a learning environment in which prospective teachers can approximate teaching practice by anticipating a lesson that they had planned. The study shows that by engaging in approximations of teaching, prospective teachers can learn to attend to some aspects of the complexity of instruction.

CHAPTER 3
METHODOLOGY

This study explores how a novel approach to lesson anticipation facilitates prospective teachers' learning to teach. In particular, the study aims to understand whether and how a lesson-sketching tool, *Depict,* can engage prospective secondary mathematics teachers in attending to the mathematical interactions between teacher and students. The data for this study was a collected as part of the ThEMaT (Thought Experiments in Mathematics Teaching) project, by members of the GRIP[2] (Geometry Reasoning and Instructional Practices) research group.

This study poses the following research questions:

1. How do anticipations of classroom interaction about a planned lesson differ when done using a multimedia lesson-depicting environment as compared with talking through the written lesson plan?
2. What do prospective teachers attend to in the work of teaching when engaged in depicting a lesson?
3. How do prospective teachers employ the graphic resources to support their lesson depiction?

[2] GRIP (Geometry Reasoning and Instructional Practices) is a research group directed by Patricio G. Herbst. Support for the research reported in this article has been provided in part by the National Science Foundation, through grant ESI-0353285; all opinions expressed are the sole responsibility of the authors and do not represent the views of the Foundation.

In this chapter I describe the process of data collection and I introduce the lesson-sketching tool, *Depict*. I then describe the analytic approaches that were used to understand and resolve the research questions.

Setting and Context

This study was conducted with prospective secondary mathematics teachers at the time that they were involved in a teaching practicum. This practicum was a requirement for college juniors in the first (of three) semester of secondary teacher preparation program at Midwest University. To pass the practicum, students needed to both attend a weekly 1-hour seminar and participate in a field placement. Twenty-three students enrolled in this course. These prospective teachers had been paired up and assigned to observe middle or high school mathematics classes four to five hours per week. The seminar was a site for these prospective teachers to discuss issues regarding their experiences in field observation. It also served as a site for prospective teachers to gain insights into the work of teaching mathematics, thus better immersing themselves into the practice of teaching. The foci of this seminar were mathematical literacy, how mathematical literacy mediates students' thinking, attending to students' mathematical work, and knowing students.

From the fourth to the sixth seminar meeting, activities in the course focused on providing prospective teachers teaching experiences concerning students' conceptions of linear function, for the purpose of subsequently planning a lesson on the same topic. The topic of linear functions was chosen because of its importance in the secondary mathematics curriculum.

To facilitate their learning of students' conceptions of linear functions and to use those in planning a related lesson, these teacher candidates engaged in three learning activities during the seminar sessions. First, they read a document written by one of the instructors that introduced the topic of student conceptions and conceptions of slope. This document made the point that students' errors can often be traced to particular ways of thinking about a concept and described four conceptions of slope (table, proportion, formula, graph) (see Appendix A). Second, they were provided with a rubric regarding explaining concepts written by one of the instructors (Herbst, 2011). The document describes practices involved in explaining concepts and provides examples of class scenarios for each practice. Third, they annotated students' work on linear function with guiding prompts (see Appendix B). The students' work was selected from a corpus of three thousand written artifacts about linear functions. These artifacts had been previously collected from secondary school students for the purpose of practicing how to assess students' prior knowledge. The selected samples represented and illustrated students' common conceptions and associated errors regarding linear functions. After they had annotated the students' work in a set of 10 artifacts, the prospective teachers had been asked to plan a lesson on introduction to slope. In the following section, I describe their lesson planning activities and the data collection process.

Data Collection and Sources

Data collection consisted of two phases. In Phase One, data collection took advantage of an assignment that the prospective secondary teachers had, planning a lesson in pairs using a text-based planning format during the seminar meeting. In

Phase Two, nine pairs of prospective teachers were recruited to participate in a voluntary, compensated, out of class experience in which they would elaborate on their lessons in one of two different conditions: via lesson depiction or via lesson description.

Phase One: Lesson planning in text

The seminar assignment to plan a lesson engaged the prospective teachers in planning a 15-minute lesson explaining the concept of slope using text. The participants worked in pairs with their field placement partner. Considering this group of participants' limited experiences in class observation, planning, and teaching, it was appropriate to have them collaborate in pairs.

This work follows the assertion that instruction is an interactive process that occurs between teacher, students and content (Cohen, et al., 2003). It is presumed to be desirable for prospective teachers to attend to this interactive relationship when planning the lesson. In order to direct the participants' attention to the three essential instructional constructs, they were guided by the following questions when planning their lesson in text: (1) What is the mathematics that will be done? (2) What will the teacher be doing? (3) What will students be doing? In addition, the pairs were asked to estimate the time spent on each event and to make a timeline of the lesson in the seminar assignment.

Each pair was provided with a packet of blank worksheets with guiding questions (see Appendix C). This lesson plan instrument was developed based on the rubric of explaining concepts provided for the prospective teachers earlier. In addition, three resource artifacts were available, including their earlier annotations on students' written artifacts, the rubric of explaining concepts, and the document explaining the concept of the slope.

Pairs had approximately fifty minutes to plan their lesson. If they finished the planning, the instructors suggested they review their lesson and revise their lesson plan if necessary. Some pairs reviewed their lesson by role-playing.

Phase Two: Using *Depict* or describing lessons

In the second phase, nine pairs of participants were recruited for further participation in the study. Their participation was voluntary. These nine pairs were randomly divided into two groups: the Depict group and the Control (Description) group. Participants in the Depict group were invited to use *Depict* to create lesson slides based on their lesson plans. *Depict* is a graphic composition tool that provides a virtual classroom setting in which prospective teachers can depict a lesson as a slide show using graphic resources. Participants in the Control group were invited to describe orally how their lesson would unfold. Both the Depict group and the Control group sessions were held outside the seminar class and participants were compensated for their time.

The Depict group involved four pairs of participants. Each pair had one hour to anticipate their lessons through a lesson depiction. In the first five minutes of this session, the interviewer introduced the features of the tool. During the following fifty minutes, the participants depicted lessons based on their lesson plan. The participants were informed that they should start depicting their lessons from the beginning task in their lesson plan but did not have to implement all the tasks. With five minutes left in the session, the researcher asked the pair of participants to stop depicting the lesson even if they had not yet finished all the tasks planned. The researcher asked the participants what they had attended to in the lesson depiction that they had not considered when planning in text. The participants were also asked to assess the usability of the tool and to provide suggestions for future development.

The Depict group sessions were recorded in both audio and video. One camera recorded each pair's discussion and interactions, and a second recorded the screen actions projected on the projector screen. A screen recording software, Snapz Pro X (Welch, 2008), was used to capture the screen activities that participants took part in when creating the lesson slides in *Depict*.

The Control group consisted of five pairs of participants. Each pair was interviewed for one hour. In the first five minutes, the pair reviewed their lesson plan. The interview involved two stages. The first stage was a no-prompt interview. The interviewer asked the pair to elaborate on their lesson plan through the following question: "Can you describe how this lesson would unfold?" The second stage was conducted with an interview with guiding prompts. Immediately after the first stage of interview, the interviewer went over the text written in the participants' lesson plan and prompted them with guiding questions, such as: "What would you say?" "What would you do next?" In the last five minutes, the interviewer asked the participants what they became aware of that they had not considered when planning in the text format. The interview sessions were recorded in both audio and video. Table 3.1 summarizes the data collection phases and the activities that participants were involved in. Table 3.2 summarizes the data sources collected in this study.

Table 3.1 Data Collection Phases and Lesson Planning Activities

Phase	**Lesson Plan Format**	**Description**	**Guiding prompts**	**Time Spent on Lesson planning**
PHASE ONE	Text-based lesson plan	Nine pairs of prospective teachers planned a 15-minute lesson in the text-based format	· What is the mathematics that will be done? · What will the teacher be doing? · What will students be doing? · How long might it take?	Fifty minutes
PHASE TWO	Depict Group	Four pairs of prospective teachers depicted lessons in *Depict*	N/A	Fifty minutes
	Control Group (Description Group)	Five pairs of prospective teachers were interviewed	Stage#1-general (no) prompt: Could you describe how this lesson would unfold? Stage#2-with prompts: What would you say? What would you do next?	Fifty minutes

Table 3.2 Data Sources, Purposes, and Use in Answering Research Questions

Data source	Description	Participants	Goal	Research Questions
Text-based lesson plan	A 15-min lesson on conception of slope in text-based format	9 Pairs	To understand the extent to which prospective teachers plan their lessons with guiding prompts in the text-based format	RQ1 RQ2
Video and audio records (Depict Group) of participants' depiction of lessons	Participants' interactions and conversations when depicting lessons	4 pairs	To understand prospective teachers depiction of their lessons	RQ1 RQ2 RQ3
Screen actions captured in video format and Video records of projected computer screen	Participants' on-screen activities in *Depict*	4 pairs	To examine prospective teachers interactive activities with *Depict* and how the features support in lesson depiction	RQ1 RQ2 RQ3
Video and audio records (Control group)	Participants' descriptions of their lessons	5 pairs	To understand the extent to which prospective teachers anticipate their lessons without and with guiding prompts	RQ1

Introduction to *Depict*

In this section, I introduce the lesson-sketching tool, *Depict.* I start by discussing the learning theory that informs the tool's design. Then I introduce the features and functionality of the tool.

Design rationale

Depict is a software tool that allows users to anticipate and present a lesson via a slide show. The design of *Depict* is based on the assumption that learning occurs when learners interact with a "milieu" and get feedback from it (Brousseau, 1997). By milieu, Brousseau refers to the environment that the learner is acting on and receiving feedback from. To create a "milieu" for learning, *Depict* provides users opportunities to create, view, review and revise lesson slides (Herbst & Chieu, 2011). Users plan and anticipate what might happen in the teaching of the lessons. Viewing and reviewing the lesson slides may help users examine and modify their lessons.

Herbst and colleagues (2011) have proposed that two characteristics in representations of teaching are important for prospective teachers to attend to when learning to teach-- temporality and individuality. Learners of teaching need to attend to the temporal issues in instruction, including time spent on each activity and the sequence among activities. Learners of teaching also need to pay close attention to multivocal reactions of students, including attention to different students at the same time and their different ways of thinking and ideas. Further, learners of teaching need to be attentive to students' multimodal ways of communicating their thinking, such as verbal and gestural expressions and written inscriptions.

The design of *Depict* attempts to provide users opportunities to be aware of the above two demands of teaching. Consequently, in *Depict*, by creating, viewing and reviewing sequences of lesson slides, users can anticipate the development of lesson events, thus attending to temporal factors in teaching. In addition, users utilize graphic features, such as classroom templates, expressions and gestures, to attend to students' verbal and nonverbal reactions.

Overview of *Depict*

Depict is a tool developed to support representations of classroom interaction. This study aims to engage users in anticipating lessons using cartoon-based characters and classroom settings and in examining how a lesson would unfold. *Depict* has been updated to a new version since the study was conducted. I introduce the interface and features available when the study was conducted, and then I describe the differences in the new version.

When the study was conducted, the *Depict* interface consisted of three areas (see Figure 5). The central area was the canvas or working space where users drag one of the slide templates to in order to work on it and add other graphic elements, such as students' expressions. On the upper side of the canvas, users have options to manage slides, such as creating, deleting, duplicating, opening saving and naming slides. The left hand side of the canvas listed all the slides created thus far. The buttons on the bottom left corner allowed users to arrange the order of created lesson slides. *Depict* preserved all slides, even those later deleted. The right hand side listed the graphic elements users can manipulate. These graphic features will be introduced in the next section.

In the new version, above the canvas lists all the functions that allow users to manage slides (e.g. creating, duplicating, arranging, inserting). On the right hand side of the canvas, six graphic features are available for users to click, drag, and drop onto the workspace. These graphic features include classrooms, furniture, supplies, teachers, students and dialogue (Herbst & Chieu, 2011)

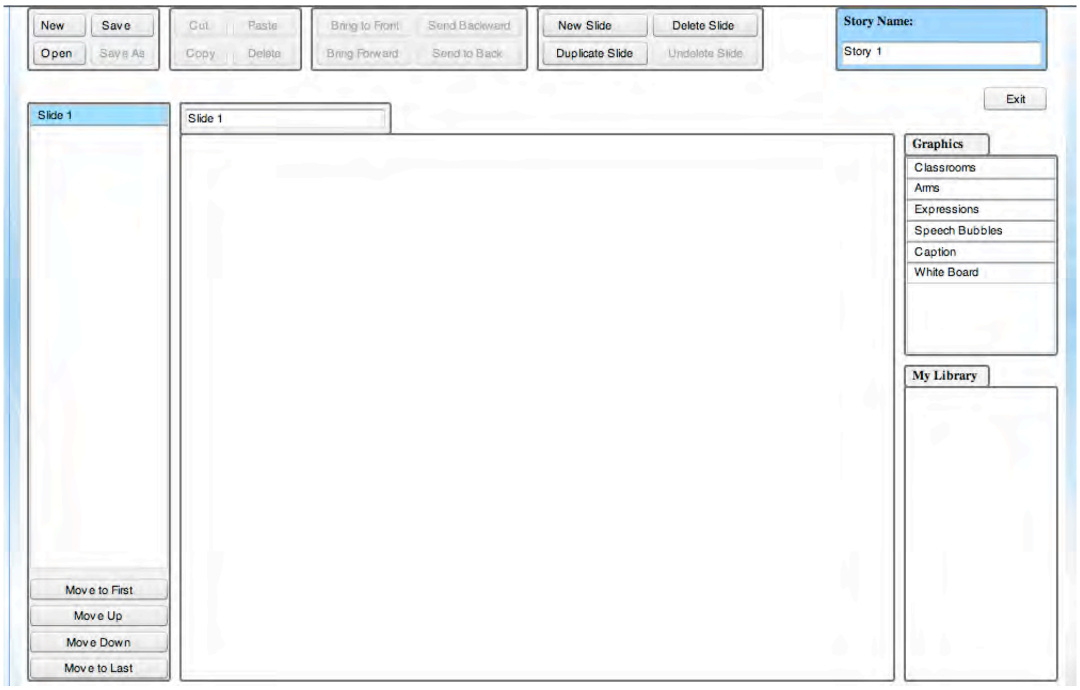

Figure 5. The interface of *Depict* shown when the study was conducted

Graphic features in *Depict*

Six key graphic features allowed users to create slides to represent their lesson: classroom templates, hand-arm gestures, facial expressions, speech bubbles, caption boxes and a boardwork creating tool, *Inscribe*. These graphic features invited users to attend to classroom discourse and students' verbal and nonverbal interactions. In the following sections, I describe these features and how they may encourage users to attend to different instructional issues.

Classroom templates

Classroom templates represent classroom settings in which teaching events occur. For this study, six templates of classroom shots were available. These templates represented typical classroom views. And the templates included students and teacher represented using the character set ThExpians P (Herbst & Chieu, 2011). These were static templates in which users could not select or arrange characters and fixtures. The static nature of templates served as a shortcut to save users' time to compose various elements for each classroom setting. In addition, it would encourage them to pay close attention to depicting the teaching events.

Four templates were provided with a view of the teacher. Users could choose from a set of female or male teacher templates. These templates placed the virtual teacher in four locations. Two (out of four) templates have the virtual teacher standing at the board facing the class at the center and at the side. The other two templates have the virtual teacher writing on the board at the center and side, respectively. The board in this series of templates was blank, thus encouraging users to create the board work. These templates illustrate what the class would look like from an observer's point of view. This point of view allows a prospective teacher to observe and examine his or her teaching.

One of the templates shows a class of students sitting in rows facing the board. This template illustrates the perspective that a teacher takes when standing at the board. These virtual students represent diverse ethnic background (as shown by skin color), gender (as shown by head shapes, eye shapes, and hairstyles), and affiliation groups (as shown by their T-shirts). The class setting is assigned with fixtures, such as desks, chairs, bookshelves, posters and billboards. By default, students have blank faces and no arms. Users are expected to assign gestures and expressions to the virtual students if they want to change that default. This feature is expected to enable prospective teachers to visualize various students in class and their verbal and nonverbal reactions.

Another template is a close-up shot of a board, which invites users to create text or objects that the teacher or students may potentially produce. This template, along with the ones with view of teacher, is expected to engage users to pay close attention to the board content in their lessons.

Users can select a template from the scroll-down menu on the right hand side of the interface. Users can delete or duplicate a slide. On the left hand side, all the created slides are listed, even those deleted. Users can move up or down the slides to rearrange their order.

Hand-arm gestures

While the templates give the virtual teacher character two arms, the virtual student characters have none. Users can anticipate students' gestural actions and add these elements to the virtual students. Considering some typical students gestural actions in high school settings, *Depict* provides ten gestures: left/right arm-neutral, raise left/right hand, explaining, pointing, thinking, writing, biting pencil, and peace. These gestures may convey instructional meanings of students to the teacher. For example, the "biting pencil" gesture illustrates that the student may be confused and is thinking about a problem. The "raising left/right hand" gesture may show that the student has a question, and is asking for clarification. The "pointing" gesture may illustrate that the student is referring to something on the board.

Expressions

The virtual teacher and student characters are not given facial expressions. Users are expected to attend to characters' facial reactions when they depict a lesson, especially to students' expressions. Female and male characters have different eye-shapes. Both female and male characters have the same types of expressions. These expressions are in three major categories: positive (excited), neutral (neutral, neutral-speaking) and negative (bored, confused/frustrated, uncertain).

Adding expressions to characters may reveal the users' attention to characters' nonverbal thoughts and moods. For example, a student is displaying a "neutral" emotion, indicating that he/she may be listening to the lecture. A student is "excited", indicating that he/she has just solved a problem or understood a concept that the teacher has just explained. A student is "bored", showing that he/she is not interested in the topic. A student is "confused", showing that he/she does not know the task requirement or the teacher's explanation. The negative types of expression draw more of teacher' attention and require teacher's further prompts.

Speech bubbles

Users are expected to create teacher-student dialogue via speech bubbles. By specifying the dialogue, users must articulate the teacher's instructions. Users must consider students' responses, including mathematical thoughts and possible misconceptions.

To add a speech bubble, users have to click the "speech bubble" button on the right hand side of the interface. A blank speech bubble then appears on the slide and users can type text in it. Users can add more than one speech bubble on the same slide.

Board content creating tool--Inscribe

Inscribe is a tool that allows users to draw diagrams or create text as board content. This tool is expected to encourage users to explicitly plan the notes, questions, examples and representations that the virtual teacher would use. Users may also anticipate the boardwork that students might produce during the lesson. Objects created in *Inscribe* are saved in a Resources folder. This allows users to retrieve these objects for further use. For example, users may retrieve an object created earlier and attach it to a later slide as a way to keep the board content consistent. Users may retrieve a stored object and modify it so as to show the development of the board content.

Caption boxes

Caption boxes allow users to describe and illustrate the events that the given templates or other graphic features cannot represent. This feature can be employed in various occasions. For example, users may write "Students work in pairs for five minutes" in a caption box to indicate that students are working on the assigned task. A caption box "Teacher walks around to check students' work" shows that the virtual teacher is supervising students' work, instead of standing at the board, lecturing.

The graphic elements in *Depict* are expected to facilitate users' (prospective teachers) learning to attend to the multimodal communications in the classroom, including verbal (speech bubbles), nonverbal (gestures, facial expressions), and visual modes inscriptions. These graphic elements are expected to direct prospective teachers' attention to their own instructional activities and their attention to students' thinking. *Depict* aims to provide prospective teachers the opportunities of anticipating the complexity of instructional events, and thus facilitate their learning to teach.

Data Analysis

The methodology for the analysis of data includes three approaches. First, I use Systemic Functional Linguistics (Halliday & Matthiessen, 2004; Martin & Rose, 2003) to identify and compare the number of class events that the prospective teachers planned or anticipated in the text-based lesson plan, lesson depiction, and lesson description context. Second, I perform task analysis (Doyle, 1983; Herbst, 2003) to examine how prospective teachers attended to details of their lessons when rendering their lessons using *Depict*. Finally, I analyze both the use of features and users' behavior (Bailey & Konstan, 2003) to annotate how the prospective teachers use *Depict*'s graphic features to implement their lessons and how those features draw their attention to instructional details.

A multimodal data corpus

To address the overarching research question - how do rich-media resources facilitate prospective teachers' attention to instruction - I gathered a multimodal data corpus. Multimodality refers to all modes of meaning-making systems involved in communication, such as text, images and speech; it creates “an integral component of a larger sense-making resource system” (Lemke, 2002). This corpus allows me to examine how prospective teachers develop their lessons using different resources. This corpus involves different modes of data sources, including written, verbal and visual.

I consider the written lesson plans, lesson slide show created through lesson depiction and lesson descriptions as distinct representations of teaching. Because they all include class events, it is reasonable to identify what events prospective teachers plan and anticipate in these different formats, and compare them.

To show the affordances of *Depict*, I employ three approaches. I hereby briefly introduce these three approaches and the corresponding objectives and I will then elaborate the methods in the following sections respectively. First, I draw resources from Systemic Functional Linguistics (Halliday & Matthiessen, 2004) to compare the class events anticipated by two groups: the Depict group and the Description group. This comparison allows me answer Research Question#1 to find out whether lesson depiction in a visual mode provides prospective teachers opportunities to attend to class events that a verbal mode does not. In addition, this comparison clarifies how lesson depiction enables prospective teachers to anticipate more of the classroom interactions than lesson description.

To answer Research Question #2, I apply a task analysis (Doyle, 1983; Herbst, 2003)to examine the planned tasks and investigate the lesson depiction process to determine how prospective teachers attend to the complexity of instruction relative to planning in the written mode. Finally, to answer Research Question #3, I evaluate the use of graphic features and users' behavior (Bailey & Konstan, 2003) in lesson depiction. In doing so, I examine how *Depict*'s graphic features facilitate the users' attention to instructional details.

The following table illustrates the methods I adopt to answer corresponding research questions:

Table 3.3 Methodology and Research Questions

Research question	Approach/ Description	Method	Steps	Data sources
RQ1	Compare the Depict group and the Description group	Discourse analysis-SFL	1. Determine the number of tasks in different formats of lesson plans. 2. Conjunction analysis to determine the class events. 3. Participant-Process analysis on class events 4. Compare the averages of Participants and Processes per task	Text lesson plan, lesson description, discussion and lesson depiction
RQ2	Compare the tasks in text format and their development in lesson depiction	Task analysis	1. Identify the goal, resources and operations of a task in lesson plans. 2. Compare the developments of tasks in lesson depiction	Text lesson plans; lesson depiction discussion and lesson slides
RQ3	Inspect the affordances of *Depict*'s graphic features	Graphic features and screen action analysis	1. Inspect the occurrences of each feature used Investigate the types of actions on each feature. 2. Observe the moments in which modifications occur	The use of graphic features and screen actions in the Depict Group

Discourse analysis of lesson events: Comparing two groups

To examine the affordances of lesson depiction, it is important to differentiate the details of teaching events anticipated in the lesson depiction condition from those in the lesson description condition. I intend to first show and describe the class events involved in the text-based lesson plans that all participants created. Then I inspect and compare how these class events were developed later in two different conditions.

To answer Research Question#1 (How do anticipations of classroom interaction about a planned lesson differ when done using a multimedia lesson-depicting environment as compared with talking through the written lesson plan?), the analysis involves two steps.

In step one, I perform a task analysis to determine the number of tasks that participants planned in each format: lesson plan, lesson depiction and lesson description. I use the model of the academic task (Doyle, 1983, 1988; Herbst, 2003, 2006) to examine the tasks the lesson plans propose. According to Doyle (1988), the three components of a task are: (1) the product (final goal that students need to achieve); (2) resources (verbal or written information available to students); (3) operations (manipulations of resources to achieve the task goal). At this stage, I only identify the goals of each task and identify the number of tasks planned or anticipated in each format of representations of lessons. It is important to consider the degrees of details of teacher and student involvement per task and compare those, because of the extent to which the amount of tasks may differ among different representations of lessons. For example, the participants may ambitiously plan many tasks in their written lesson plan, but may not provide extensive detail of how teacher and students would interact to accomplish those tasks. In contrast, the participants may predict fewer tasks when using the *Depict* tool because they would need time to design the specific teacher-student dialogues and interaction moves in classroom activities. Hence it is appropriate to compare the degrees of details of teacher-students interactions anticipated per task between two conditions of lesson anticipation. This step helps me to proceed in identifying the details of class events in each task.

In step two, I use discourse analysis to evaluate the details of class events involving teacher and student that participants anticipated through different representations of lessons. To do this, I apply Systemic Functional Linguistics (SFL). I follow Halliday and Matthiessen in assuming that ideational meanings are construed in discourse. The ideational meanings refer to how discourse reveals ones' experiences in the world. These meanings can be revealed by an examination of the transitivity structure of the clause: Processes[3], Participants, and Circumstances (Halliday & Matthiessen, 2004, p. 169).

To create text from three different representations of lessons, the interviews were transcribed (for the description group). In the lesson depiction group, I created multimodal textual transcriptions (Thibault, 2000) that include the transcriptions of pairs' discussion and the descriptions of the comics-based lesson slides[4]. With these transcripts and the text-based lesson plans, I performed a conjunction analysis to parse these representations of lessons into clauses. I consider a lesson unfolded as a sequence of events, so conjunctions that show additive and sequential relationships[5] (such as *"and", "then", "after", "before"*)

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[3] The terms of discourse analysis are capitalized.

[4] For example, if a double-entry table is presented on the board by the virtual teacher on the lesson slide, I describe it as "the teacher presents a double-entry table on the board."

[5] According to Martin and Rose (2003), there are four kinds of logical relations—addition, comparison, time and consequence (p. 112-113).

(Martin & Rose, 2003) help to identify class events that the prospective teachers anticipate in their lessons sequentially.

I particularly looked at clauses where Participant-Process structures are related to the teacher's or students' experiences in lessons. Specifically, I looked at the clauses in which the processes and participants are the teacher or student(s) involved in class events. So a clause, such as "I'm going to make a new slide" from the lesson depiction transcription does not count for the analysis purpose, because "going to make a new slide" refers to the activity of lesson depiction and "I" refers to a particular prospective teacher in the study, not the teacher role in a lesson. A clause, "we'd give them a table with the time and each of our respective distances at that time" from the interview transcription, is related to the teacher's action in class. Because "we" indicates the teacher who will "give" students a table. This analysis resulted in a corpus of clauses related to activities or descriptions involving teacher's or students' role in class. Then I classified these clauses according to Participant-Process system.

Processes are language choices that represent ones' experiences. According to Halliday and Matthiessen (2004), there are three major types of processes to represent experiences. Clauses containing material processes are "clauses of doing-&-happening: a 'material' clause construes a quantum of change in the flow of events as taking place through some input of energy" (p. 179). In the context of class events, a material clause could be "the teacher draws a table", "students write down the answers on the sheets" or "the teacher walks around." While material processes are related to outer experiences, mental clauses are "clauses of sensing: a 'mental' clause construes a quantum of change in the flow of events taking place in our own consciousness" (p. 197). In the context of class events, a mental clause could be "students remember the formula" or "students don't like homework." Finally, relational clauses "serve to characterize and to identify" (p. 210). In the context of class events, a relational clause could be "this student is smart" or "the teacher is in the front of classroom."

Besides the above three major types of processes, the verbal process is considered as one of the subsidiary types of processes. Verbal clauses are "clauses of saying" and "they contribute to the creation of narrative by making it possible to set up dialogic passages" (p. 252). Verbal clauses could be represented through verbs that report messages or through verbs accompanied with direct quotes. In the context of class events, a verbal process that reports in a clause could be "the teacher talks to the class". A verbal process that is accompanied with a direct quote in a clause could be "the student answers: 'X'.

To inspect the differences of the teacher and students experiences among various representations of lessons, it is important to ask the above experiences "by whom?" Hence, I examine the Participant along with the process types. "Teacher" and "students" are two major Participants in class events. To detect the extent to which the prospective teachers were able to anticipate individual students' involvement in their lessons, I further distinguish students' involvement in class events into two categories: "students as a class" and "students as individuals." I identify students are seen as a class when the participants referred them as "they", "students" or "the class". Students are seen as individuals when the participants named students or referred them as "'one student", "he", "she."

Teacher and students, the two major Participants, might play either an active role or a passive role in class events. For example, in a class event: "the teacher gives worksheets to students", "teacher" is an active Participant, and "students" are passively participating in the event. Another example: "Bob replied to the teacher", Bob is an individual who participates in the class event, and the teacher passively got the reply. Therefore, I distinguish the active and passive roles of teacher and students in each class event. I label the passive roles of teacher and students as "teacher as a recipient", "students as a class of recipients" and "students as individual recipients."

To sum up, I identify the occurrences of types of Participants involved in class events in lesson plan, lesson depiction and lesson description conditions. The types of Participants include active and passive roles: "teacher", "teacher as a recipient", "students as a class", "students as a class of recipients", "students as individuals" and "students as individual recipients." I also examine the occurrences of the Participant-Process structure in each class event. Within each type of active Participants, I look at the Process types involved in class events—material, mental, relational, and verbal.

Table 3.4 Types of Participant-Process Structure Examined in Class Events

Types of Participant	Participant-Process	
Teacher	Active role	Teacher-Material Teacher-Mental Teacher-Relational Teacher-Verbal
	Passive role	Teacher as a recipient
Students as a class (SC)	Active role	SC-Material SC-Mental SC-Relational SC-Verbal
	Passive role	Students as a class of recipients
Students as individuals (SI)	Active role	SI-Material SI-Mental SI-Relational SI-Verbal
	Passive role	Students as individual recipients

Due to differences in the total number of class events and the tasks planned in each condition, I calculate the average of class events of each Participant-Process structure per task. Thus I can compare the degrees of detail the prospective teachers could anticipate in their lessons.

Additionally, I use the Mann-Whitney test, a non-parametric test, to detect the significance among variables between the Depict and the Description groups. Because the relatively small size of the study sample, normal distribution of the data could not be assumed, and the variance might be high from original scores. Hence, it is appropriate to convert the scores to ranks and to use a non-parametric test.

Further, because the study involves data from two independent samples between two conditions, the Mann-Whitney test can evaluate the differences of details of class events between the two comparing groups.

Task analysis: Comparing lesson depiction and lesson plan

To answer Research Question#2: What do prospective teachers attend to in the work of teaching through lesson depiction? I examine how *Depict* supports participants' lesson anticipation. I conduct case studies to gather as much detailed information as possible regarding prospective teachers' lesson anticipation using *Depict* (Yin, 2006). This approach allows me to explore different prospective teachers' experiences and learning from the activity of depicting lessons.

I conduct a more detailed task analysis to examine how lesson depiction develops the tasks planned in the text format. Unlike an earlier approach in which I only obtained the number of tasks in different representations of lessons, here I examine the three elements of a task: goal, resources, and operations (Doyle, 1983, 1988; Herbst, 2003, 2006). It is important to employ these three components to determine the tasks involved in a lesson because they allow me to investigate the degrees of detail with which the participants anticipate their lessons. Particularly, it helps to examine whether and in what ways they provide resources for students to implement the tasks, and whether they identify students' thinking and reactions involved in the tasks.

I first investigate, in each pair of participants' lesson plans, the three elements of each task. I then inspect how the lesson depiction process changes these three elements within the same task. For this purpose, I focus on the discussion between the pairs as well as their work creating lesson slides in *Depict*. I parse transcriptions of discussions and corresponding screen actions according to which task was being undertaken. I then examine the pairs' comments on the original tasks in the lesson plan and their subsequent insights into the modifications of those tasks when generated in lesson depiction. Additionally, I observe how the same tasks are depicted via lesson slides. I then identify emerging themes and use the three constructs in instruction (teacher, students, mathematics)(Cohen, et al., 2003) to frame and synthesize the analysis.

Graphic features and screen action analysis of *Depict*

To answer Research Question#3: How do prospective teachers employ the graphic resources to support their lesson planning? I examine how *Depict*'s graphic lesson planning. For this purpose, I enumerate the frequency of each features used and observe users' behavior while using the tool (Bailey & Konstan, 2003). Specifically, I describe how prospective teachers utilized the graphic features and interacted with the tool. The analysis includes three steps.

First, I inspect the frequency and ways in which each feature was utilized to represent teacher-student interactions. For example, in order to determine the level of involvement by the teacher and students, I observe and compare the use of teacher-view and student-view templates. I also examine the use of speech bubbles to represent the teacher's and students' interventions.

Second, I examine the types of actions performed with each feature. I focus on the moments that users created and modified the application of each graphic feature. For example, I investigate the moments users create, duplicate and change a teacher-view or student-view template. I look into the moments in which users decided to include a caption box or edit its content.

In the final step, I probe the affordances of visualizing graphic representations. I hypothesize that visualizing the lesson slides allows users to examine and refine their anticipation of lesson events. Hence, I identify two moments, *viewing* and *reviewing*, in which users can regard the lesson slides created thus far. I define *viewing* as an action that occurs when users are looking at the slide they are currently creating and have not yet gone to create the next slide. I define *reviewing* as an action in which users are looking at a series of slides that they have created that far. I then investigate instances of modification within each feature at these two moments. For example, regarding the template feature, I look at whether and in what ways users *change* their selections of templates when *viewing* or *reviewing* the slides. I also look at whether and in what ways the users *edit* the contents in speech bubbles or in caption boxes when *viewing* and *reviewing* the slides.

Summary

In order to study how rich-media resources facilitate prospective teachers' attention to mathematical interactions with students, I investigate prospective teachers' lesson planning and anticipations done via different resources and tools. The study consists of three pieces of analysis. The first part of analysis, in responding to Research Question #1, I compare the similarities and differences of lesson anticipations done through *Depict* and through lesson description. To do this, I evaluate the details of class events involving teacher and student roles generated from the two representations of lessons. In the second part of analysis, in answering to Research Question #2, I conduct task analysis to examine how depicting lessons develops the mathematical tasks planned in text format. Finally, in the last part of analysis, in responding to Research Question #3, I inspect the use of graphic features and observe user's behavior to investigate how *Depict* enables prospective teachers to attend to instructional details.

CHAPTER 4

ANTICIPATING TEACHER AND STUDENT ROLES IN LESSONS

In this section, I address Research Question#1: How do anticipations of classroom interaction about a planned lesson differ when done using a multimedia lesson-depicting environment as compared with talking through the written lesson plan?

To examine the affordances of the *Depict* tool, it is important to differentiate the details of class events anticipated via two different representations: lesson depiction and lesson description. All participants worked in pairs to plan a 15-minute lesson explaining the concept of slope in the text format. Then these participants were divided into two groups: the Depict group and the Control (Description) group. The Depict group participants used the *Depict* tool to create a comics-based slide show to represent their lesson. The Description group participants were asked to verbally describe their lesson. The study hypothesizes that the *Depict* tool, with graphic resources, encourages prospective teachers to attend to more instructional details, specifically teacher's and students' involvement, than their counterparts in the lesson description condition.

I drew resources from Systemic Functional Linguistics (SFL) to evaluate the details of class events involving teacher and student roles in different representations of lessons. I analyzed the Participant-Process[6] structure in each clause related to teacher's or students' experiences in class. I defined a class event as a clause in which the agent or the actor is the teacher or student. I identified types of Processes of each Participant in active role, including material, mental, relational and verbal Processes (Halliday & Matthiessen, 2004). I then identified the Participants involved in each type of Process – the actor of material Process, the senser of mental Process, the participant of relational Process, and the sayer of verbal Process in each clause (class event). These Participants involved in each type of Process are considered active roles in class events. I also identified the client/recipient of material Process, the phenomenon of mental Process, the Participant of relational Process, and the Receiver of verbal Process that are related to teacher or students' passive roles.

I considered students could participate in class events as a class or as an individual. Hence, I looked at three major types of Participants: "teacher", "students as a class" and "students as individuals." I also distinguished the active and passive roles of teacher and students in each class event. Hence, the passive roles were labeled as follows: "teacher as a recipient", "students as a class of recipients" and "students as individual recipients." I calculated the total class events of each type of Participant-Process structure involved in different representations of lessons.

I also performed a task analysis (Doyle, 1983; Herbst, 2003) to determine the number of tasks that the different representations of lessons include. I then calculated the average of class events per task of each Participant-Process structure.

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[6] The terms are capitalized to represent elements of discourse analysis.

It is important to take into consideration the degrees of details of teacher and student involvement *per* task and compare those, because of the extent to which the number of tasks may differ among different representations of lessons. For example, the participants may ambitiously plan many tasks in their lesson plan, but may not provide extensive detail of how teacher and students interact to accomplish the tasks. In contrast, the participants may anticipate fewer tasks when using the *Depict* tool because they would need time to design the specific dialogues between the teacher and students.

In the following sections, I first show and describe the results of class events of each Participant-Process structure involved in the lesson plans that all participants created. This aims to show the common traits that the participants planned using text. Then I show and compare the detail of class events involved in *Depict* lessons and lesson descriptions.

Characteristics of Lesson Planning in Text

In the lesson plan, the participants worked in pairs to plan a 15-minute lesson explaining the concept of slope. They were provided with a packet of worksheets containing questions that were designed to help guide the teachers in planning their lessons. The participants were asked to make sure that their lessons addressed the teacher, the students, and mathematical concepts. Afterward, their lesson plans were collected for analysis.

Tasks and class events

In this section, I first present the number of tasks in each lesson plan. Note that I only identified tasks in lesson plan that were later anticipated in lesson depiction or in lesson description. And I only examined the Participant-Process structures in class events in these tasks in lesson plan, lesson depiction and lesson description conditions. I then show the total class events that each type of Participant was involved in lesson plan.

Table 4.1 Number of Tasks in Each Lesson Plan Anticipated

Group	Prospective teacher	Number of tasks anticipated
Depict	Sienna & Pamela	4
Depict	Samantha & Millie	4
Depict	Ellie & Elliot	3
Depict	Beth & Serena	4
Description	Desmond & Wanda	9
Description	Amanda & Wallace	6
Description	Margot & Daedra	5
Description	Douglas & Daliah	8
Description	Jack & Sheila	6

The above table shows that the number of tasks the Description group anticipated was relatively higher than that in the Depict group. The participants may ambitiously plan many tasks in their lesson plan. And when they were later interviewed, it might be relatively easy for them to describe their lessons. However, the participants may anticipate fewer tasks when representing lessons using *Depict* because they would need time to design the details in teacher-students interactions.

The Participants in this piece of analysis were classified as teacher, students as class, and students as individuals. They were considered to be playing either an active role or a passive role in class events. By active role, I mean that Participants appear in the role of actor of material Process, senser of mental Process, a participant of relational Process or sayer of verbal Process. By passive role, I mean that Participants appear in the role of recipient of material Process, phenomenon of mental Process, participant of relational Process or receiver of verbal Process. For example, in an event, “teacher talks to students”, teacher is a sayer, an active role, while students are passively receiving messages from the teacher.

Table 4.2 shows the number of class events in which the teacher role, students as class, and students as individuals, were involved actively or passively. The third column shows the number of class events in which the teacher role was involved either actively or passively. The numbers between the parentheses shows the numbers of class events in which teacher role was active and passive respectively. For example, among those in the Depict group, Sienna and Pamela’s lesson plan contained 7 class events that involved the teacher role. The teacher role was actively involved in all seven of these class events. This leaves that there was no class event in which the teacher role was passively involved. That is, teacher was not considered as a recipient in these class events in the lesson plan.

Table 4.2 Number of Class Events in which Teacher and Students are Involved in Lesson Plans

Group	Prospective teacher	Teacher	Students		Total of Class events
			As a class	As individuals	
Depict	Sienna & Pamela	7 (7/0)	0 (0/0)	0 (0/0)	7
Depict	Samantha & Millie	11 (11/0)	9 (5/4)	0 (0/0)	16
Depict	Ellie & Elliot	13 (13/0)	10 (2/8)	0 (0/0)	15
Depict	Beth & Serena	18 (18/0)	9 (6/3)	0 (0/0)	24
Description	Desmond & Wanda	20 (20/0)	9 (2/7)	0 (0/0)	22
Description	Amanda & Wallace	15 (15/0)	4 (4/0)	0 (0/0)	19
Description	Margot & Daedra	26 (26/0)	14 (7/7)	0 (0/0)	33
Description	Douglas & Daliah	23 (23/0)	4 (1/3)	0 (0/0)	24
Description	Jack & Sheila	25 (25/0)	7 (2/5)	0 (0/0)	27

The fourth column shows the numbers of class events in which the students were involved as a class actively and passively. The numbers between the parentheses shows the occurrences of class events in which students-as-class were active and passive respectively. For example, in the Depict group, Samantha and Millie's lesson plan contained 9 class events that involved students as a class. The collective student role was actively involved in 5 of 9 class events. This leaves 4 class events in which the collective student role was passively involved. That is, the collective student role was considered as a recipient in these 4 class events in the lesson plan.

The fifth column in the above table shows that none of the prospective teachers considered students as individuals involved in class events. The last column shows the total number of class events identified in lesson plans. The number of class events in the Description group was generally higher than the Depict group because the tasks anticipated in the Description group are more than those in Depict group. Hence, it is reasonable to calculate the average of class events per task in which types of Participants were involved and compare them.

Participants

In this section, I present the mean average of class events of types of Participants' involvement per task in the lesson plans. Table 4.3 shows the average of class events involving each type of Participants per task n the lesson plans that nine pairs of prospective teachers created. For example, in Sienna and Pamela's lesson plan, there were 4 tasks and 7 class events in which the teacher role was involved (see above two tables). Therefore, there are on average 1.75 class events per task in which the teacher role would be involved (either actively or passively).

Overall, these prospective teachers anticipated more teacher involvement than student involvement per task; in other words, their lesson plans contained little student participation. This observation is consistent with research on novice teachers' lesson planning (Leinhardt, 1993). Furthermore, the prospective teachers generally anticipated that they would interact with students collectively, and rarely included one-on-one exchanges.

The results of the Mann-Whitney test show that, between the Depict group and the Description group, when using a text-based lesson planning tool, there were no significant differences in their anticipation of the extent to which the three types of Participants would be involved in the lesson (see Table 4.4).

Table 4.3 Average Number of Class Events Per Task of Participants involvement in Lesson Plans

Group	Prospective teacher	Teacher	Students		
			As a class (SC)	As an individual (SI)	Total
Depict	Sienna & Pamela	1.75	0.00	1.25	1.25
Depict	Samantha & Millie	2.75	2.25	0.00	2.25
Depict	Ellie & Elliot	4.33	3.33	0.00	3.33
Depict	Beth & Serena	4.50	2.25	0.00	2.25
Description	Desmond & Wanda	2.22	1.00	0.00	1.00
Description	Amanda & Wallace	2.50	0.67	0.00	0.67
Description	Margot & Daedra	5.20	2.80	0.00	2.80
Description	Douglas & Daliah	2.88	0.50	0.00	0.50
Description	Jack & Sheila	4.17	1.17	0.00	1.17

Table 4.4 Mann-Whitney Test of Groups Comparing Teacher and Students role involvement in Class Events

	Depict Group (n=4)		Description Group (n=5)			
	Mean Rank	Sum of Ranks	Mean Rank	Sum of Ranks	U	P
Teacher	5.00	20.00	5.00	25.00	10.000	1.000
Students as a class	5.75	23.00	4.40	22.00	7.000	.461
Students as individuals	5.63	22.50	4.50	22.50	7.500	.264

In the following sections, I further discuss how each type of Participant's Processes are involved in the lesson plans. I organize these sections by types of Participants (teacher, students as a class, student as an individual) respectively.

Teacher's processes

The following table (see Table 4.5) shows the average number of class events per task in which different types of teacher's processes are involved in lesson plans. I consider that the teacher role could be involved as active or passive in class events. In class events, when the teacher role is involved passively, I labeled it as "teacher as recipient." When the teacher role is considered active in class events, I categorize teacher's active involvement according to different types of Processes: material, mental, relational, and verbal. After identifying the number of class events in each Teacher-Process category, I divided that number by the number of tasks in the lesson plan to the average number of class events per task in each category.

Table 4.5 Average Number of Class Events per Task of Teacher Processes in Lesson Plans

Group	**Participants**	**Teacher-Recipient (Passive)**	**Teacher-Active**				
			T-Material	T-Mental	T-Verbal	T-Relational	Total
Depict	Sienna & Pamela	0.00	0.25	0.00	1.50	0.00	1.75
Depict	Samantha & Millie	0.00	1.25	0.00	1.50	0.00	2.75
Depict	Ellie & Elliot	0.00	2.00	0.00	2.34	0.00	4.33
Depict	Beth & Serena	0.00	2.75	0.00	1.75	0.00	4.50
Description	Desmond & Wanda	0.00	1.00	0.00	1.23	0.00	2.22
Description	Amanda & Wallace	0.00	0.67	0.00	1.83	0.00	2.50
Description	Margot & Daedra	0.00	2.20	0.00	3	0.00	5.20
Description	Douglas & Daliah	0.00	0.38	0.00	2.5	0.00	2.88
Description	Jack & Sheila	0.00	1.67	0.17	2.34	0.00	4.17

Overall, the teacher role was not considered as a recipient in the lesson plans. This may indicate that the participants viewed the teacher role as a leading actor who initiates the instructional events, and they did not include any events where the students would interact with the teacher.

In the lesson plans, the "teacher" role was primarily involved in verbal and material Processes and minimally in relational and mental Processes. The lack of consideration of relational Process may indicate that the participants did not regard teacher's characterization, identification or quality as being important to their lesson plans. Besides, teacher's mental Process was rarely included in the lesson plans.

The result of Mann-Whitney test shows that there were no significant differences between the two groups' anticipation of teacher involvement of these Processes (see Table 4.6). This result shows that all prospective teachers in this study share similar traits when considering the teacher role's involvement in text-based lesson planning.

Table 4.6 Mann-Whitney Test of Groups Comparing Teacher Processes in Class Events

	Depict Group (n=4)		**Description Group (n=5)**			
	Mean Rank	Sum of Ranks	Mean Rank	Sum of Ranks	*U*	*P*
Teacher-Material	5.50	22.00	4.60	23.00	8.000	.624
Teacher-Mental	4.50	18.00	5.40	27.00	8.000	.371
Teacher-Verbal	3.88	15.50	5.90	29.50	5.500	.266
Teacher-Relational	5.00	20.00	5.00	25.00	10.000	1.000

Class processes

The following table (see Table 4.7) shows the average number of class events per task in which students would be involved as a class in the lesson plans. Students as a class were involved in two different roles—as recipients and as active participants. Student recipients are seen as taking a passive role in the class events; for example, in an event entitled “teacher shows them definition on the board”, “them” is referring to students who are passively given information. In an event entitled “teacher asks them to solve the problem”, students are given instruction but do not interact with the teacher. In contrast, as non-recipients, students were considered active participants in class through material, mental, verbal, and relational Processes. For example, in an event “students work on the given problem”, students are active participants through material Process by working on the task. The results show that the prospective teachers generally expected their students to be involved as a class of recipients (see Column: SC-Recipient) rather than a class of active Participants.

Table 4.7 Average Number of Class Events per Task of Class Processes in Lesson Plans

Group	Participants	SC-Recipient (Passive)	Students as a class (SC) (Active participants)				
			SC-Material	SC-Mental	SC-Verbal	SC-Relational	Total
Depict	Sienna & Pamela	0.00	0.00	0.00	0.00	0.00	0
Depict	Samantha & Millie	1.00	0.75	0.25	0.00	0.25	1.25
Depict	Ellie & Elliot	2.67	0.33	0.33	0.00	0.00	0.66
Depict	Beth & Serena	0.75	0.00	1.25	0.25	0.00	1.5
Description	Desmond & Wanda	0.78	0.22	0.00	0.00	0.00	0.22
Description	Amanda & Wallace	0.00	0.00	0.17	0.50	0.00	0.67
Description	Margot & Daedra	1.40	0.40	0.60	0.20	0.20	1.4
Description	Douglas & Daliah	0.38	0.00	0.00	0.00	0.13	0.13
Description	Jack & Sheila	0.83	0.17	0.17	0.00	0.00	0.34

Regarding students' active involvement, students as a class were rarely anticipated to be verbally participating in the lessons. Instead, students were expected to think or perform an action to a certain extent. Few descriptions of students regarding their identification or characterization were generated in lesson plans. These results show that students were expected to "do" things during the lesson. Although they were expected to "know" or "think" in certain ways, the teachers did not anticipate the exact ways in which students might verbally express their thoughts.

The results of Mann-Whitney test show that there were no significant differences between the two groups with regard to their anticipation in these categories (see Table 4.8). This shows that all prospective teachers in this study share similar considerations regarding students' involvement in the lesson plan.

Table 4.8 Mann-Whitney Test of Groups Comparing Class Processes in Class Events

	Depict Group (n=4)		**Description Group (n=5)**			
	Mean Rank	Sum of Ranks	Mean Rank	Sum of Ranks	U	*P*
Students as class-Material	5.25	21.00	4.80	24.00	9.000	.798
Students as class -Mental	6.00	24.00	4.20	21.00	6.000	.317
Students as class -Verbal	4.63	18.50	5.30	26.50	8.500	.662
Students as class -Relational	4.88	19.50	5.10	25.50	9.500	.884

Individual student processes

In the lesson plans, the prospective teachers could not successfully anticipate individual students' participation, with the exception of Sienna and Pamela's plan (see Table 4.9). This pair of participants anticipated that the teacher would request individual students to come to the board to accomplish assigned tasks at different times. These individual students are recipients of teacher's direction at the moment when they are called, and then they, as individuals, would finish the assigned tasks in the role of active Participants.

Table 4.9 Average Number of Class Events per Task of Individual Student Processes in Lesson Plans

Group	Prospective teacher	SI-Recipient (Passive)	Students as individuals (SI) (Active participants)				
			SI-Material	SI-Mental	SI-Verbal	SI-Relational	Total
Depict	Sienna & Pamela	0.50	0.75	0.00	0.00	0.00	1.25
Depict	Samantha & Millie	0.00	0.00	0.00	0.00	0.00	0.00
Depict	Ellie & Elliot	0.00	0.00	0.00	0.00	0.00	0.00
Depict	Beth & Serena	0.00	0.00	0.00	0.00	0.00	0.00
Description	Desmond & Wanda	0.00	0.00	0.00	0.00	0.00	0.00
Description	Amanda & Wallace	0.00	0.00	0.00	0.00	0.00	0.00
Description	Margot & Daedra	0.00	0.00	0.00	0.00	0.00	0.00
Description	Douglas & Daliah	0.00	0.00	0.00	0.00	0.00	0.00
Description	Jack & Sheila	0.00	0.00	0.00	0.00	0.00	0.00

Class Events Comparison between Lesson Depictions and Lesson Descriptions

In this section, I compare the details of lesson events anticipated from the lesson depiction group and the lesson description group. For the lesson depiction group, I integrated all the semiotic resources created from their proposed activities and generated text-based transcriptions of their lesson depiction plans, including the comics-based lesson slides, the discussion around the depiction, and the screen actions taken. In the Description group, I transcribed the interviews in which the prospective teachers were asked to verbally describe how their lesson would unfold. They were given no prompts, only the single interview question: “could you describe how your lesson would unfold?” As with the text-based lesson plans, I used conjunction analysis to identify clauses as class events in the transcriptions (Halliday & Matthiessen, 2004). Then I identified the Participant-Process system to categorize these class events. Finally, I compared the average number of class events per task in which types of Participants and Processes were involved in the lesson depiction group and in the lesson description group.

I first present the comparison of Participants involved between lesson depiction and lesson description. I then discuss in detail each type of Participant-Process structure and the comparison between the two groups.

Participants

To show whether there is a difference in the level of anticipation of Participants between the two conditions, I first present and compare the average number of class events per task in which each type of Participant is involved in each condition. I then identify whether the differences between the two conditions reach statistical significance using the Mann-Whitney test.

The prospective teachers in the lesson depiction condition anticipated more teacher and student participation than those in the lesson description condition. Regarding the teacher role in lessons, the Depict group in average had 8.938 class events per task that involved teacher, while the Description group in average had 3.344 class events per task involving the teacher role. Regarding the role of students in lessons (including collective and individual), the Depict group on average anticipated 9.667 class events per task and the Description group had 1.727 class events per task.

The Depict group anticipated that lessons would be made up of more student involvement (9.667 events per task) than teacher participation (8.938 events per task). In addition, the *Depict* users anticipated more individual student involvement (6.792 events per task) than full-class participation (2.895 event per task). In contrast, the participants in the lesson description group did not anticipate any individual student involvement. This difference in the anticipation of individual student involvement was significant (Mann-Whitney U (2-tailed); U= .000, $p < .007$). With regard to the anticipation of students' involvement in general, combining their collective and individual activity, the two conditions are significantly different (Mann-Whitney U (2-tailed); U= .000, $p < .014$).

Table 4.10 Average Number of Class Events Involving Types of Participants

Group	**Teacher**	**Students**		
		As a class	As an individual	Total
Lesson Depiction	8.938	2.875	6.792	9.667
Lesson Description	3.344	1.727	0	1.727

These results indicate that the prospective teachers using *Depict* expected more teacher involvement, as well as student engagement in their lesson, than the other group. Additionally, the participants using *Depict* attended more to the involvement of individual students than the class as a whole. In contrast, in the verbal description of their lessons, the prospective teachers only viewed students as a class and did not identify instances of individual student participation.

Teacher’s processes

Generally, the *Depict* users envisioned more teacher involvement in each type of Process than their counterparts in the lesson description condition (see Table 4.11). Among these variables, the only one that is significantly different between the two groups is verbal Process (Mann-Whitney U (2-tailed); U=1.000, $p<.027$), perhaps as a result of the speech bubble feature in the *Depict* tool that encourages users to create dialogues.

Depict users considered “teacher” a passive participant in their lessons that students may interact with. For example, in an event “students responds to teacher’s question”, teacher is passively given with responses from students. The prospective teachers in lesson description group, however, did not anticipate that teacher role could be passive.

Table 4.11 Average Number of Class Events Involving Teacher Processes

Group	Teacher as Recipient (Passive)	Teacher (Active)			
		Teacher-Material	Teacher-Mental	Teacher-Verbal	Teacher-Relational
Lesson Depiction	0.063	3.563	0.167	3.917	1.229
Lesson Description	0.000	1.811	0.133	1.294	0.107

Class processes

The prospective teachers in the lesson description group anticipated interacting more with students as a class of recipients (0.864 events per task, see Table 4.12) than those in the lesson depiction condition (0.708 events per task).

This comparison may indicate that the prospective teachers in the lesson description condition were more likely to view students as passive Participants. However, the difference between the two groups was not significant (Mann-Whitney U (2-tailed); U= 9.000, p=.806)

As for the class Processes, the *Depict* users generated more anticipations than the other group, which may imply that in the lesson depiction condition, the participants were better able to attend to students' participation in general. This may be partly a result of the fact that the classroom template with the view of students in the *Depict* tool allows users to visualize the presence of students and hypothesize students' engagement. However, the group differences in the above variables did not achieve statistical significances from Mann-Whitney test.

Table 4.12 Average Number of Class Events Involving Class Processes

Group	**Students as a class of recipients**	**Students as a class (SC)**			
		SC-Material	SC-Mental	SC-Verbal	SC-Relational
Lesson Depiction	0.708	0.354	1.104	0.292	0.417
Lesson Description	0.864	0.309	0.418	0.033	0.102

Individual student processes

The lesson description prospective teachers did not generate any anticipation of individual students' involvement (see Table 4.13)**.** Given their limited classroom observations and teaching experiences, these prospective teachers may not have had any context to envision individual student participation in their lessons.

However, one of the classroom templates provided in the lesson depiction shows a classroom full of diverse students seated in rows. This graphic feature seems to increase users' awareness of students, thus encouraging users to envision individual students' verbal or nonverbal reactions in their lessons. From the results of Mann-Whitney test, the Processes—relational, material, verbal—between the two conditions were significantly different (Mann-Whitney U (2-tailed); U=.000, $p < .007$ for the above three Processes). The group differences in the mental Process did not achieve statistical significance (Mann-Whitney U (2-tailed); U=5.000, $p = .094$).

Table 4.13 Average Number of Class Events Involving Individual Student Processes

Group	**SI-Recipient**	**Students as individuals (SI)**			
		SI-Material	SI-Mental	SI-Verbal	SI-Relational
Lesson Depiction	0.188	1.479	0.479	2.042	2.604
Lesson Description	0.000	0.000	0.000	0.000	0.000

As for the anticipation of collective and individual students' verbal involvement, the group difference is also significant (Mann-Whitney U (2-tailed); U=.000, $p < .011$). These results indicate that the *Depict* users were better able to attend to students' potential verbal participation in lessons than their counterparts.

Summary

Thus far I have presented the extent to which the prospective teachers anticipated lesson details through different representations of lessons. I first presented the Participants and Processes involved in class events per task of a lesson in the text format that all prospective teachers planned. Then I examined the same variables in both the lesson depiction and lesson description conditions. In the following section, I summarize the results.

The prospective teachers generally showed similar tendencies of planning in the text, which I will now enumerate. First, in the written lessons, "teacher" plays a dominant role and the students rarely participate. The prospective teachers only considered students' collective involvement and they did not anticipate individual students' participation. Second, the "teacher" is actively involved in lessons through verbal and material Processes. This observation concurs with previous studies that teachers typically plan lessons with a series of activities that reminds them what to do or prepares teachers' future actions (Hill, et al., 1983; McCutcheon, 1980; Shavelson, 1983; Yinger, 1980). Third, the prospective teachers generally anticipated that students would passively participate in lessons (i.e. they would be "recipients"). Regarding students' active participation, they were only expected to think or perform an action to some extent. For example, "students think about subtracting negative numbers"; "Students put their (coordinate) points into a table". Finally, in the lesson plan, the prospective teachers were rarely able to anticipate individual students' involvement. Overall, the results show that although thinking about teacher's leading role in activities in their lesson plans, these prospective teachers did not focus equally on students' active participation when planning. This observation is consistent with the research on novice teacher lesson planning (Borko, et al., 1988; Peterson, et al., 1978; Roskos & Neuman, 1995)

Comparing the Participants and Processes involved in the lesson depiction and in the lesson description, the prospective teachers in the two groups showed different trends of lesson anticipation, as the following paragraphs illustrate.

First, the *Depict* users anticipated more teacher and student involvement in class events per task in their lessons than their lesson description counterparts. In particular, similar to the planning in the text, the prospective teachers in the lesson description condition did not anticipate any individual student participation.

Second, the *Depict* participants anticipated more teacher active involvement in various types of Processes than their counterparts. Third, the *Depict* users anticipated that the "teacher" might be involved as a recipient, while the lesson description teachers did not. This may show that lesson depiction allows the prospective teachers to envision that the teacher could have a passive role with which students interact.

Fourth, the *Depict* users anticipated more collective students' Processes than the lesson description participants. Anticipating students' possible behavior or thinking in lesson is recognized as a characteristic in expert teachers' planning (Lampert, 2001; Leinhardt, 1993; Schoenfeld, et al., 2000). However, the lesson description participants were more likely to view students collectively as passive Participants.

Finally, while the participants in the lesson description did not envision any individual student participation, their counterparts were able to incorporate students' individuality into their lesson plans. The *Depict* users in particular were able to include students' verbal involvement, a significant difference from the other group.

CHAPTER 5

TASK ANALYSIS OF LESSON PLAN AND LESSON DEPICTION

In this section, I seek to address Research Question#2: What do prospective teachers attend to in the work of teaching when engaged in depicting a lesson? I examine and compare the tasks that each pair of participants planned in the text format and those they anticipated using *Depict* to create lesson slides.

All four pairs of participants planned more tasks in text than they did in *Depict*. I examine and compare the tasks that were both planned and anticipated in the two formats. I identify the goals that the participants intend students to achieve in each task, the resources that the participants make available for students to accomplish those goals, and the operations that the participants anticipate students would need to take for achieving the tasks. I compare the above three elements of tasks in each pair of participants' lesson plans and lesson depiction.

Within each task, I also describe the screen actions that the participants made when depicting lessons. I particularly focus on the moments that the participants created, viewed, reviewed, and revised slides. I then examine how and to what extent these screen actions in *Depict* afforded the participants opportunities to attend to the complexity of the interactive work of teaching.

Case #1: Ellie and Elliot's work

In Ellie and Elliot's work, three tasks from their lesson plan were anticipated in *Depict*. They implemented these three tasks using twelve lesson slides. They planned to have students observe a given table with two variables and graph the table.

Anticipating Task #1

The first task required students to read a given table. In their lesson plan, Ellie and Elliot wrote:

The teacher will give the students a table such as

hours	Total Distance (miles)
1	30
2	60
3	90

They will ask the students questions that connect to their prior knowledge, such as "How many miles did the car travel during the first/second/third hour?" (assuming the children have had practice looking at tables). This will take approximately 1-2 minutes.

Figure 6. The first task in Ellie and Elliot's lesson plan.

The goal of this task from the lesson plan is for students to answer the questions regarding the distances traveled after a certain amount of time (one, two and three hours). The resource provided for students to achieve the goal is the table. The pair of participants assumed that students have prior knowledge of reading a table, thus are able to answer the questions. However, Ellie and Elliot did not specify the operations required to read the table. For example, the operation involves subtracting total distance at n hours from total distance at (n-1) hour to see how far they traveled in one hour.

When Ellie and Elliot began to depict the lesson, they intended to copy their lesson plan. They first chose a slide template with the virtual teacher standing at the center and facing class at the board. They drew the table as the one in the lesson plan on the board. This table consists of two columns: the left column indicates the time in hours and the right one shows the total distance in miles. The table also includes three pairs of numbers to represent the hours and the total distance in miles. Then Ellie copied from the lesson plan and typed "how many miles did the car travel during the first hour?" into a speech bubble for the virtual teacher (see EE-S01-v1).

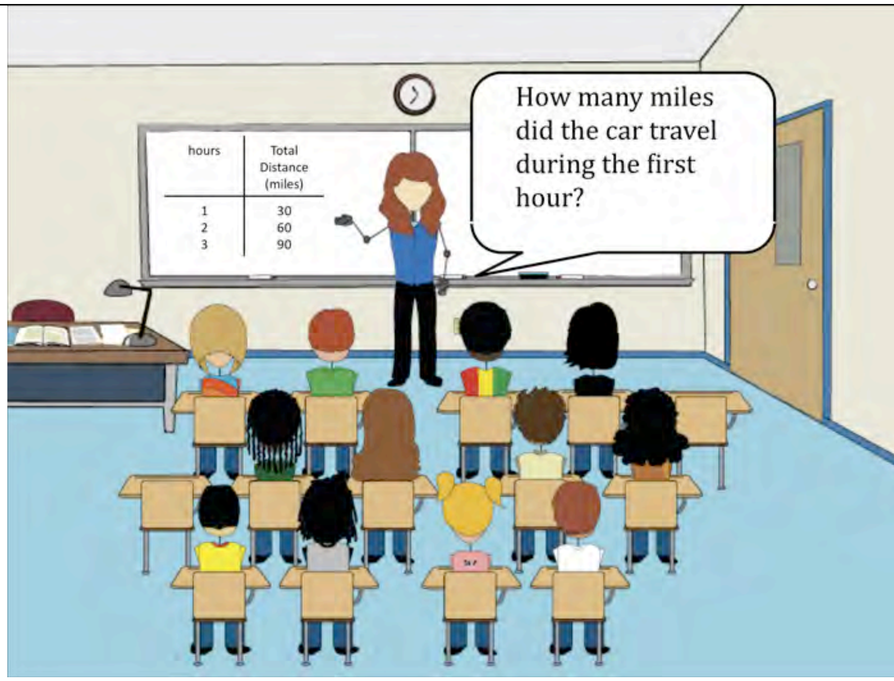


Figure 7. EE-S01-v1[7]: The question posed by the virtual teacher was copied directly from Ellie and Elliot's text-based lesson plan.

After Ellie typed up the dialogue, Elliot read the slide and commented that the teacher would not pose the question to the students without setting up the question first:

79	Elliot	….. I mean she wouldn't be like, she wouldn't-- I don't think that would be like the first thing she would say to the class, you know, …

After they realized that they needed to elaborate on their lesson plan, they modified the virtual teacher's instruction to include the context story of the table about a traveling car, and demonstrated an example of how to read a pair of

[7] All slides are remade from the original slides. Original slides are stored in Depict and are retrieved from the screen capture tool. However, the texts in speech bubbles or caption boxes are written in a font that is too small to read. The texts in the remade slides are magnified. The callout arrows may be in different orientations than those in the original slides. The callout windows may be at different locations in the remade slides. The texts and all graphic elements are kept the same as in the original slides.

numbers from two columns in the table. She then posed a question prompting students to read another pair of numbers from the table. The virtual teacher also has a female-excited expression on her face (see Figure 8).

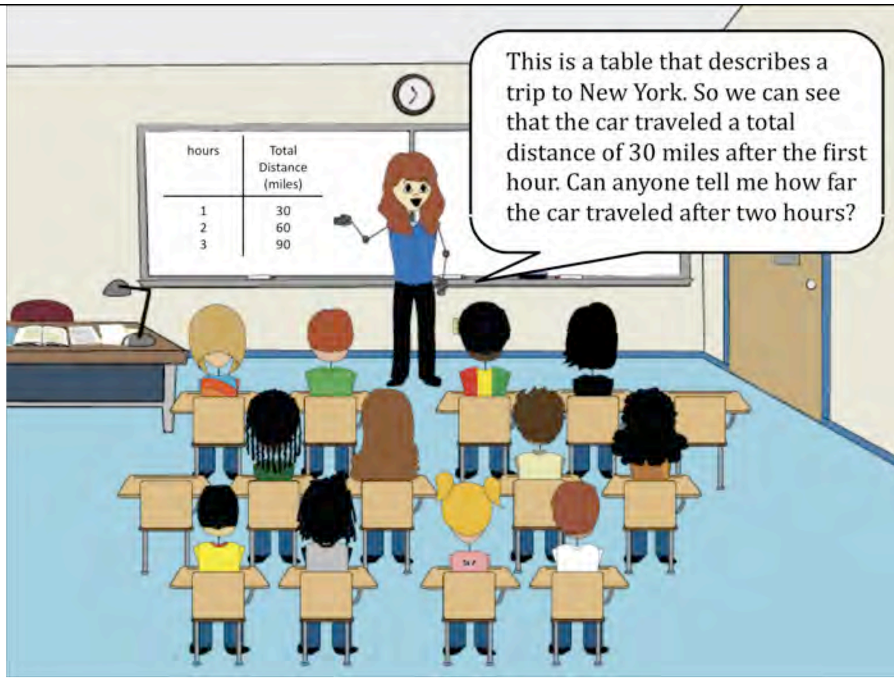


Figure 8. EE-S01-v2: The virtual teacher sets up the question.

Upon finishing the first slide, Ellie and Elliot duplicated it. In doing so, they could have all graphic elements from the first slide without composing them again. All they had to do was to change the virtual characters' dialogue. However, when they were viewing the duplicated slide and thinking about what might happen next, they realized that there should be students' responses to the teacher's initial question. A slide template with a class of students should be the next slide. And the slide that was duplicated with the teacher standing at the board could be moved to later.

131	Ellie	Um, should we have a kid, a kid should probably answer. I guess we should have done the kids face on this one. I'll just move that one to later. Who do you think would answer? [laughs]

They inserted the slide template with a class of students. They chose a male-neutral speaking expression for a student who was sitting in the first row and assigned a speech bubble with the answer to the previous question.

Figure 9. EE-S02: A male student, sitting in the front row, answers with an expression.

The next slide was the teacher's response to the student' answer and a follow-up question (see Figure 10). In this slide, duplicated from the first slide with a table on the board, the virtual teacher was standing at the board and at the center. Elliot also assigned the virtual teacher with a neutral-right arm[8].

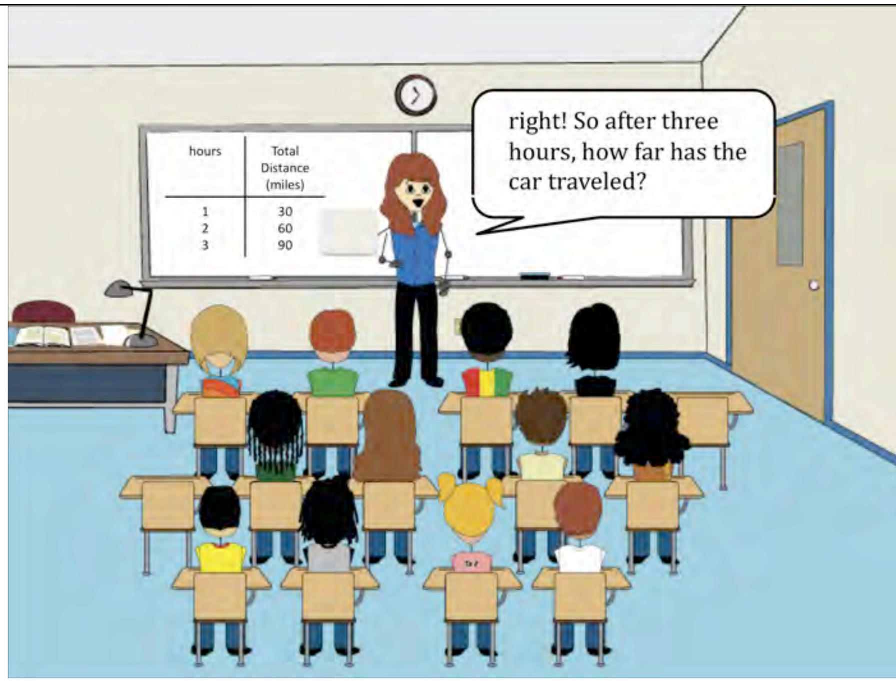


Figure 10. EE-S03: Teacher responds to the student's answer and asks a follow-up question.

The follow-up slide is a student's answer to the teacher's question. This slide has the view of a class of students. Elliot first typed up the response in a speech bubble, but later dragged it closer to a student sitting in the first row, rather than the one who answered the previous question.

Ellie pointed to the student who answered the previous question on the computer screen and suggested that he would know the answer too and would raise his hand. Then Elliot had this student raise his right hand and had a male-neutral expression. The student who was answering the current question has a male-neutral speaking expression (see Figure 11).

[8] Due to a technical defect of Depict software tool, in this slide, the table on the board blocked the virtual teacher's original right arm. So Elliot assigned a neutral right arm to the virtual teacher.

157	Ellie	I bet that kid would probably raise his hand.
158	Elliot	This guy?
159	Ellie	Let's take out the first one.
160	Elliot	[laughs] You want to give it to him then?
161	Ellie	No, I'm just—He could have his arm up.
162	Elliot	Okay, good one. [laughs]

Unlike a previous slide, in which there was only one student answering with a neutral-speaking expression, in the current one, two students were involved in the mathematical task. Besides the student who was providing the answer, another student raised his hand showing that he would also know the answer.

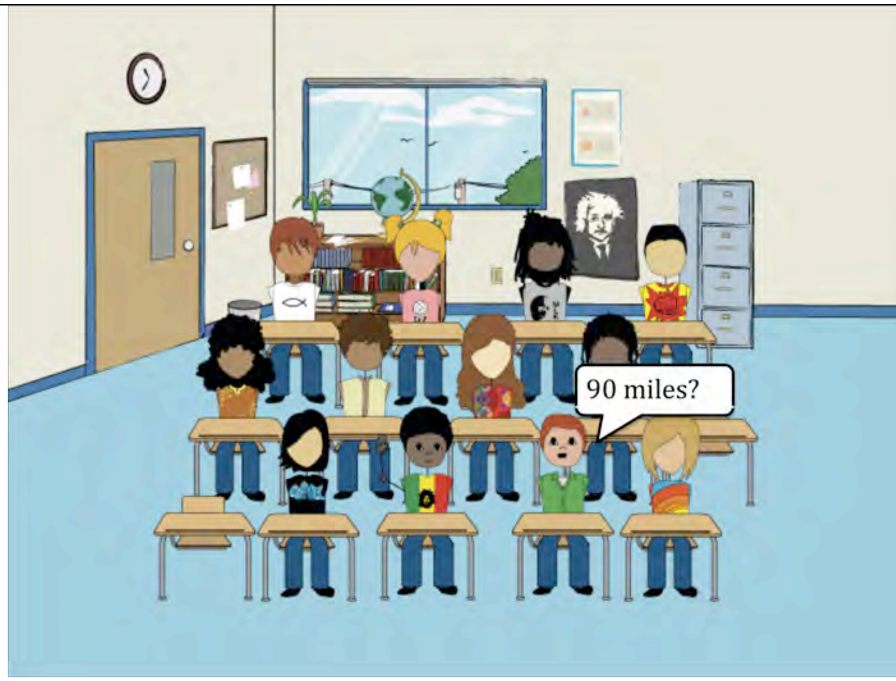


Figure 11. EE-S04: More than one student were involved in response to the question.

Analytical commentary on Task #1

The above is the first task in Ellie and Elliot's lesson and is easy to accomplish. However, the degree of attention to instructional details increased when the pair depicted the lesson. In their lesson plan, they only stated that the teacher would give students a table and ask them questions from the table. However, they did not specify how the teacher would set up the task. Also absent were students' actions in response to teacher's question.

When depicting the lesson, the pair identified specific teacher actions to provide resources for students to accomplish the task. First, the virtual teacher presented the table on the board and provided a context of a car travelling that students might be familiar with. Second, the virtual teacher offered an example of how to read a pair of numbers from two columns. The pair of prospective teachers also depicted students' verbal and nonverbal reactions, particularly, multiple student responses.

Anticipating Task #2

The second task was asking students to observe the pattern of the values from the table and to predict how far the car would travel after a certain amount of time. This task required students to make an inference about information beyond that given in the table. In the lesson plan, Ellie and Elliot wrote:

> After presenting and briefly discussing the table of values, we could ask, "How fast is the car going?" and "How far will the car have traveled after 10 hours?" The first question gets the students think about the connection between the two columns. That is, speed is a function of distance and time, not just one or the other. Also the second question is difficult and inconvenient to answer w/ only the students' current knowledge.
> This segment should take 1-2 mins.

Figure 12. The second task in Ellie and Elliot's lesson plan.

They planned to ask students two questions. The first question was to ask students "how fast is the car going?" According to Ellie and Elliot, this question "gets the students thinking about the connection between the two columns. That is, speed is a function of distance and time, not just one or the other" (see Figure 12). The goal of this question was for students to observe the pattern of the values from the given table. Ellie and Elliot acknowledged that students would need to make the connection between the two columns from the table in order to answer the first question. However, they did not mention the resources that students would need for doing the task.

The second question asked of students was "how far will the car have traveled after 10 hours?" The goal of this question is to predict the distance of 10-hour travel. And they noted that this question "is difficult and inconvenient to answer with only the students' current knowledge." They anticipated that students might have difficulty in answering the question given their limited current knowledge. They recognized the current knowledge as a resource, but they did not see this resource as sufficient for students to accomplish the goal.

Ellie and Elliot modified the task when depicting the lesson. Particularly, they provided resources for students and anticipated students' possible responses. After the students' answer to the previous task, Ellie and Elliot decided to have the virtual teacher respond and prompt further questions. They chose a slide template of the teacher standing at the center facing the class with a blank board (see Figure 13). And they discussed having the virtual teacher ask students to predict how far the car would travel after 10 hours. This question required students to read the table, interpret the given information from the table and make a prediction. Before typing up the virtual teacher's question, Elliot commented:

182	Elliot	I guess we should probably duplicate.... duplicate this because we want the table up there, right?

Elliot noticed that the table is a resource for students to answer the question. Therefore, there is a need to make the table available for students. Hence, Elliot duplicated the first slide in which the teacher was standing at the board facing the class and a table was up on the board. And then he typed up the virtual teacher's question: ”Ok, good. So can anyone predict how far the car will have traveled after 10 hours?”

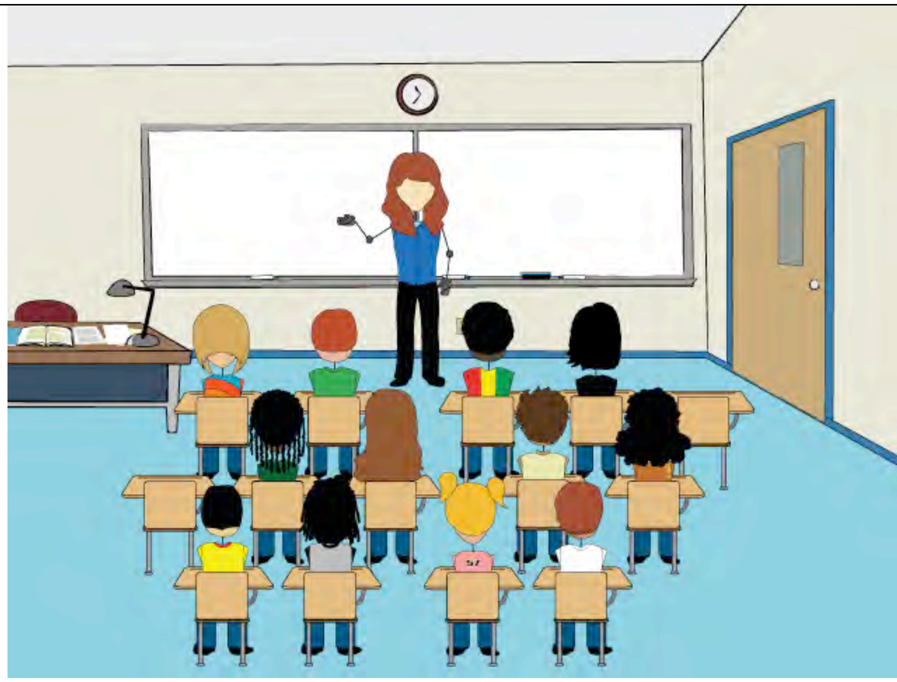


Figure 13. EE-S05-dlt: This slide was deleted after the participants realized that the table from previous task should be on the board.

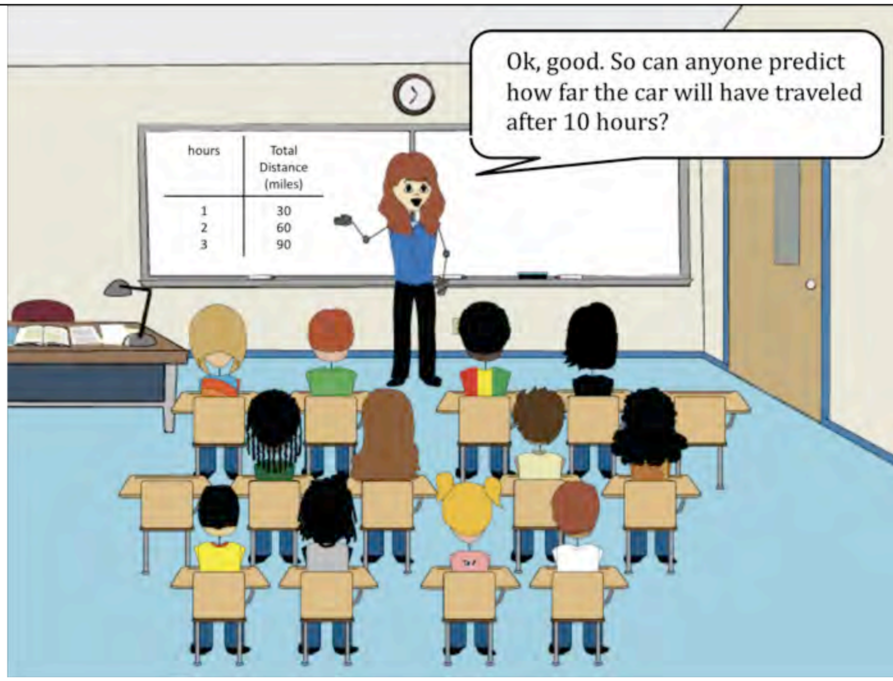


Figure 14. EE-S05: This slide was duplicated from the first slide to preserve the board content.

After typing up the teacher's question, Elliot suggested that students may be puzzled, and Ellie agreed and proposed that students need time to think about the question:

187	Elliot	Then I think there should be some puzzled people. And once again we can't get this table on here[9]. [pause 10s] Think anyone else is gonna come up with an answer?
188	Ellie	I think they would think about it for a while.
189	Elliot	Let's put some puzzled looks, or uncertain. Let's put it [a facial expression] on that guy. [laughs] Okay.
190	Ellie	Um.

[9] Elliot was referring to a technical problem that the table on the board was shown out of scale.

Elliot first put male-uncertain expressions on two students who were sitting in the first row and the third row respectively. Then he put a female-uncertain expression on a student who was sitting in the second row.

Then Ellie and Elliot continued discussing what students would think about the teacher's question. They hypothesized the differences in students thinking. They anticipated that students may not be able to get the answer for the distance traveled after 10 hours, but students may be able to observe the pattern of the given three pairs of numbers regarding time and distance. To identify students' possible thoughts on the question, Elliot reviewed the previous slide (see EE-S05) in which the virtual teacher posed the question. He pointed to the two columns of the table on the screen to indicate that the distance is equal to time multiplied by thirty (Turn #193). Ellie also proposed that students might find the difference of the distance between every one hour was thirty, thus students might add thirty ten times to obtain the answer (the distance traveled after 10 hours). This instance showed that the pair was able to hypothesize students' different ways of thinking. Later, they concluded that students might be able to observe the relationship between the two variables, even though students might not get the answer to the teacher's question right away.

191	Elliot	What do you think they will be thinking about?

192	Ellie	I don't know, I think someone might make the connection that it's going (30 miles every hour.)[10]
193	Elliot	(times 30, times 30) times 30, times 30, right?
194	Ellie	Uhhuh. [pause 5s] I don't know they might say something like, can't you-- I don't know add 30 ten times or something like that.
195	Elliot	Mmhmm.
196	Ellie	Like maybe not get the answer but kind of see the relationship.

As a result, in the same slide with a class of students, another student who was sitting in the first row replied: "Isn't it, like, going up by 30 each time?" with a male-neutral speaking expression. This slide showed the student's observation of the changing pattern from the information given in the table. This pattern is that with each additional hour, the distance increases by 30 miles. In this slide, in addition to the nonverbal responses of uncertainty shown from three students, the fourth student has both verbal and nonverbal reactions.

[10] Parentheses indicate overlapping speech.

Figure 15. EE-S06-v1[11]: Multiple students participated verbally and nonverbally.

After the student's response, Ellie and Elliot discussed how the virtual teacher should reply and rephrase the student's idea. They first chose a slide template with the teacher standing at the center and facing the students as slide #7, and typed up the teacher's response: "very good! So you are saying that every hour, the car is going 30 miles."

Analytical commentary on Task #2

Comparing what they had planned in the lesson plan, Ellie and Elliot became aware of several significant instructional features in lesson depiction. First, they duplicated a previous slide in which a table was on the board, which provided a resource for students to answer a follow-up question. Second, they predicted students' possible difficulties in responding to the question and their possible

[11] Later, when Ellie and Elliot reviewed this slide, they made a slight change on it, which will be labeled as EE-S06-v2.

emotional reactions, as well. Third, they realized that students needed time to contemplate the question. Fourth, Ellie and Elliot hypothesized what students could achieve given their current knowledge. They anticipated that students may be able to observe the pattern of the two columns in the table, but would not predict the total distance of 10-hour travel. Although in the lesson plan, they noted that the question would be difficult for students, they did not probe further about what students could achieve given their current knowledge.

Anticipating Task #3

The third task posed in the lesson plan was graphing the given values from the table and extending the graph with new values. Ellie and Elliot wrote:

> The teacher and the students collaboratively graph the table. She will help the students see a pattern and help them to extend the graph using new values. She will help them to see that as x changes by a unit of 1, y changes by 30. The mathematics that will be used is transferring data from a table to a graph and evaluating the information a graph gives us.

Figure 16. The third task in Ellie and Elliot's lesson plan.

Ellie and Elliot identified the goal of this task as to graph the values on a coordinate plane and ultimately evaluate information from a graph. Students would need to observe a pattern between a table and a graph and transfer data from one representation to another. Students would also need to graph points on a coordinate plane. Although they stated that the teacher would help students in graphing the table, they did not specify how the teacher would help or what explanations would be provided as a resource.

As Ellie and Elliot continued depicting the lesson, they were working on how to introduce the third task. They read and referred to their lesson plan of what their intention was for the task. In the previous task, they had indicated that it was hard to answer the question regarding predicting the distance of 10-hour travel given students' current knowledge. Hence, the question may set up the need to graph the given information in the table. They discussed students' prior knowledge and whether students would be able to graph points from the table.

213	Ellie	So we, yeah. [pause 6s] We said that it was um, that question's hard to answer with the current knowledge that they have. So maybe we—[pause 5s] So maybe right there she can start graphing it?
214	Elliot	Okay, do you-- I mean do they even know about graphs?
215	Ellie	I think we assumed they knew what a graph looked like and what a table looked like but not in this like--
216	Elliot	Well if I said like find the point ((9,5)).
217	Ellie	(Oh yeah.) I think they would know that.
218	Elliot	Yeah, I think so too. [pause 5s]

After the agreement that students would know how to graph points, Elliot typed:" Can we graph this?" right after the virtual teacher's earlier response to students in EE-S07. He also chose a female-neutral speaking expression on the teacher's face.

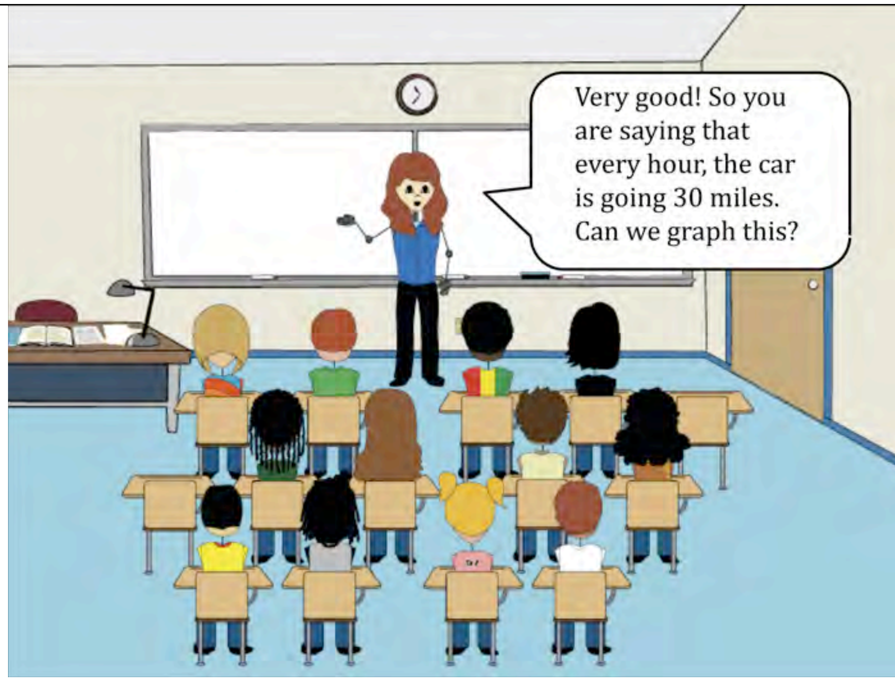


Figure 17. EE-S07-v1: The teacher responded to a student's reply and suggested graphing the points.

Ellie commented that no student would respond to the teacher's proposal regarding graphing the points, so the teacher should proceed to graph the table in the next slide. Elliot chose a slide template with the teacher writing on the left side of the board. Then, after creating the speech bubble for the teacher, Elliot realized that there was a table on the left side of the board, so the teacher should graph the points on the right side of the board. Then he changed the slide template to the one of the teacher writing on the right side of the board and created a caption box written with "table" on the left side of the table in order to save the time it would take to create the table.

Elliot's changing of the slide background indicates that viewing the slide helps them examine the board work they presented in class and allows them to think about how to manage the board work. It also helps them to visualize the space and the context of the classroom that they are engaged in.

After changing the slide background in which the virtual teacher was standing on the right side of the board and writing, Elliot typed in the speech bubble:" So, if we think about the numbers in the table as sets of two points, we can graph these points, right?" and he asked Ellie's opinion about the virtual teacher's explanation of the relationship between the table and the graph.

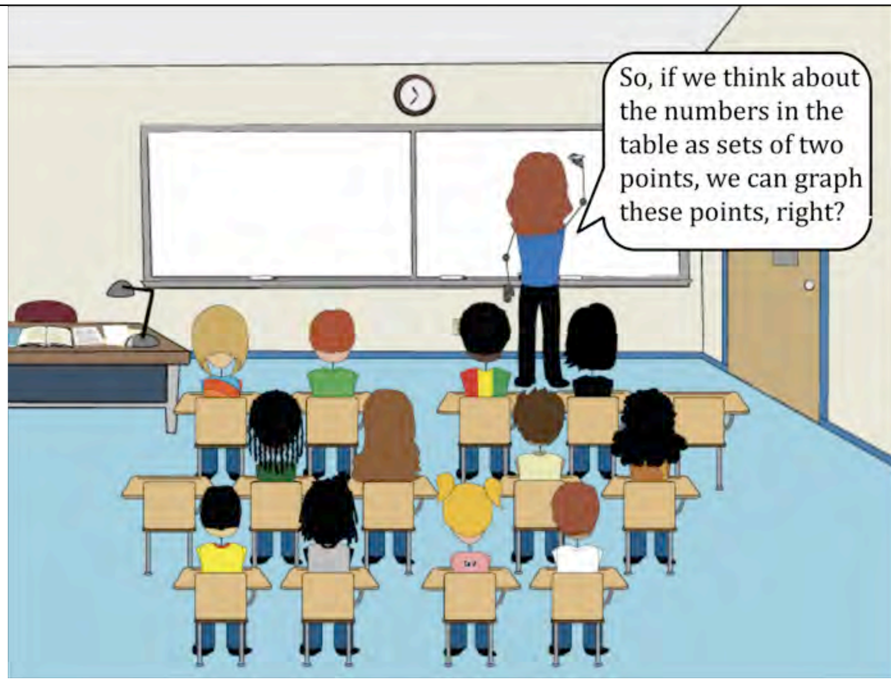


Figure 18. EE-S08-v1: The teacher was graphing on the right side, instead of left side.

230	Elliot	And the table should still be there. So I guess, or on her other side. [types] [pause 25s] What do you think?
231	Ellie	I don't know, I think sets of two points would be kind of confusing. [Elliot: I know, I know.] But if you said so, um, the number of miles traveled depends on how-- how long the car is

		gone, so we'll say our X values are independent, y'know what I mean, I-- or the hours and the distance traveled is our dependent. I don't know that they—(I know, I don't know that they would know that either.)
232	Elliot	(I feel like that would be kind of confusing too.)
233	Ellie	Um…

Ellie and Elliot were discussing how to explain the connections between the table and the graph, specifically the connection between the two variables in the table and the coordinate points in the graph. Like what was proposed by Ellie in Turn 231, she first described the two variables in the table, the relationship between distance and time. Then she tried to relate to the notions of dependent and independent variables and the coordinate values in a graph. As a result, both Ellie and Elliot were not content with the idea.

They reviewed the lesson plan and found that the task was to graph the table. In Ellie and Elliot's lesson plan, two tasks were presented—the second task was reading the table and the third task was graphing the table. However, the transition from one task to another was absent in the text, which is what Ellie and Elliot were working on at the moment. They were trying to make connections between two presentations and find out how to better explain it to the students, but they had difficulties in doing so.

So far, Ellie and Elliot had created eight slides. However, they were stuck at the point where the virtual teacher needed to explain the connection between the table and graph representations. Hence, the interviewer asked them to review the slides that they had composed from the beginning.

They reviewed the lesson starting from the first slide. On the first slide, the virtual teacher was introducing the table and asking a question based on the given information from the table. When introducing the table, the virtual teacher was saying:” This is a table that describes a trip to New York.” Elliot edited this introduction and made it explicit that it is a car's trip. Then he commented on the slide:

241	Elliot	… I feel like it should say, on the left side is the hours, just so—just to say this basically, so we can see that the car travel total distance 30 miles in the first hour.

As a result, after the virtual teacher introduced the context of the table, she further explained what each column of the table represents: “In the left column, we have the time in hours that the car has been driving. In the right column, it shows us how far the car has gone.” (see Figure 19) Elliot claimed that there was a need for the virtual teacher to do so because it would help students see the relationship between the two columns.

245	Elliot	…Um, because well, for-- I guess, it'll help them maybe see a relationship between this—the hour and the distance, I guess. And you're really making it explicit, I don't know how good they are at reading tables, so… [pause 30s] [types]

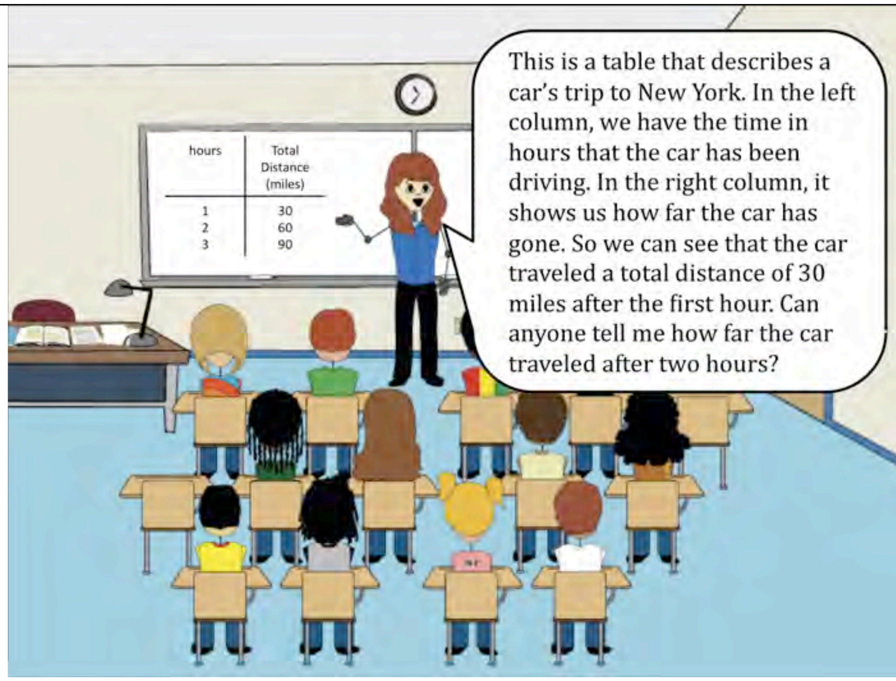


Figure 19. EE-S01-v3: The virtual teacher's instruction was revised.

They continued reviewing the slides. In Slide #6, three students were showing uncertainty about the teacher's previous question about predicting the distance traveled after 10 hours. And a student responded to the question. When reviewing this slide, Ellie commented that they needed to provide time for students' thinking about the question. Then Elliot typed in a caption box with "After a few moments."

258	Ellie	Wait, oh wait. I think you should say like after a minute or something, like after thinking occurs.
259	Elliot	Yeah. In a few moments. [Ellie: [nods]] In-descript amount of time. [pause 6s]

When Ellie and Elliot were composing Slide #6, Ellie had proposed that students would need time to think in order to answer the teacher's question.

However, it was not acknowledged on the slide. It was not until they reviewed the slide that they made a note on the slide to show that time had passed by and students had thought about the question.

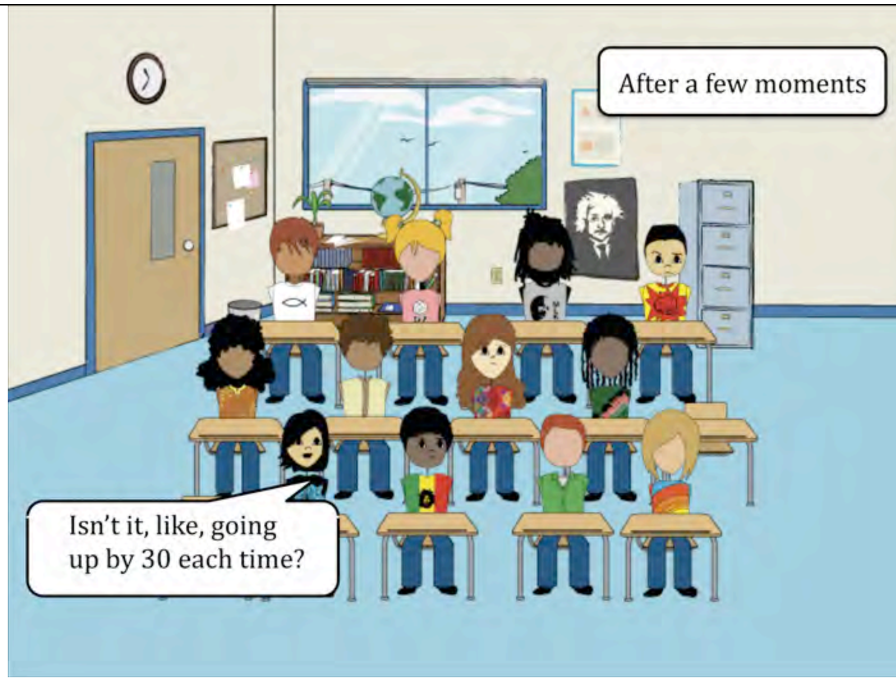


Figure 20. EE-S06-v2: A caption box indicates the time needed for student thinking.

They continued reviewing Slide #7 (see Figure 17). In Slide #7, the virtual teacher was suggesting students graph the table. But Ellie and Elliot found that there was a need to make a connection between the two representations, table and graph. Ellie first proposed that the virtual teacher should have students fill in more pairs of values in the table. In doing so, students might get a better sense of how the two columns are related. Elliot deleted the virtual teacher's suggestion "Can we graph this" on Slide #7.

261	Elliot	So would you say, there's a relationship between like the first column and the second column? We could talk about that, like the

		time and hours or the time and distance.
262	Ellie	Um.
263	Elliot	Instead of saying can we graph this.
264		[Silence 7s]
265	Ellie	Maybe she could say like, um, so we could continue-- or like if the table continued on then--
266	Elliot	Yeah, that's good, that's what we should do.
267	Ellie	But then be like-- but it might take us a while to-- to like, can-- are-- you fill in, you know, every hour and the distance traveled does that make sense? But if we just graphed it—or maybe we could just look at a graph and see it easier or something, or find a relationship to--
268	Elliot	I think they should fill in a couple more values of the table, that's a good idea. Because that would help them see the relationship. Or should we just talk about it?

However, when considering the extra time that might be spent on filling in more values in the table, Ellie reflected on the goal of the lesson, which was to introduce the slope. She was thinking about students' prior knowledge. Students might have known how to observe the pattern from a table. Since the goal of the lesson was to introduce slope, the virtual teacher should spend time on introducing the concept of "rise over run," which was not yet covered in the lesson depiction so far (Turn 269-273).

Ellie then came up with a solution for considering both the time issue and the filling of the table. She proposed that the virtual teacher work with students in filling in more values in the table and suggest graphing to better see the relationship.

269	Ellie	Um. I don't know I feel like the-- I don't know. Like the main point of the lesson is the slope [Elliot: You want to get to the graph?] and hopefully she would have covered like-- well no you want to get to like finding the slope like rise over run or what it means and, y'know what I mean?
270	Elliot	Right. What are you saying-- so would--
271	Ellie	Right, I would assume that, at this point she's um… but they've learned about maybe.
272	Elliot	Found some patterns?
273	Ellie	Yeah, found some relationships before.
274	Elliot	Okay.
275	Ellie	I don't know.
276	Elliot	So what do you think she would say next, we could fill out—well did she ask--
277	Ellie	Well you could have her do a couple more, but then maybe like say… I don't know. That it's-- you know what, sometimes it's not going to be easy to just go in and fill in every line of the table, so you might want to find a relationship or a way to--

Hence, Ellie noted how to make a connection between the table and the graph. Specifically, she identified the need for graphing a table, which is to better see the relationship of the two variables from the table. The pair had not attended to this issue when planning in text, and they were not aware of the issue when first composing the slide either.

After the discussion, Elliot typed in Slide # 7 "So there is some sort of relationship between how long the car has been driving and how far it has gone?" With Ellie's suggestion, Elliot continued typing on the slide "Maybe we could see this relationship better if we tried graphing these points." The virtual teacher introduces the need for graphing the table. She states a relationship between two variables in the table, and explains that graphing may help to see this relationship. Ellie and Elliot made a transition from the previous task of reading a table to the following task of graphing the table. Such transition between two tasks had not been stated in their lesson plan.

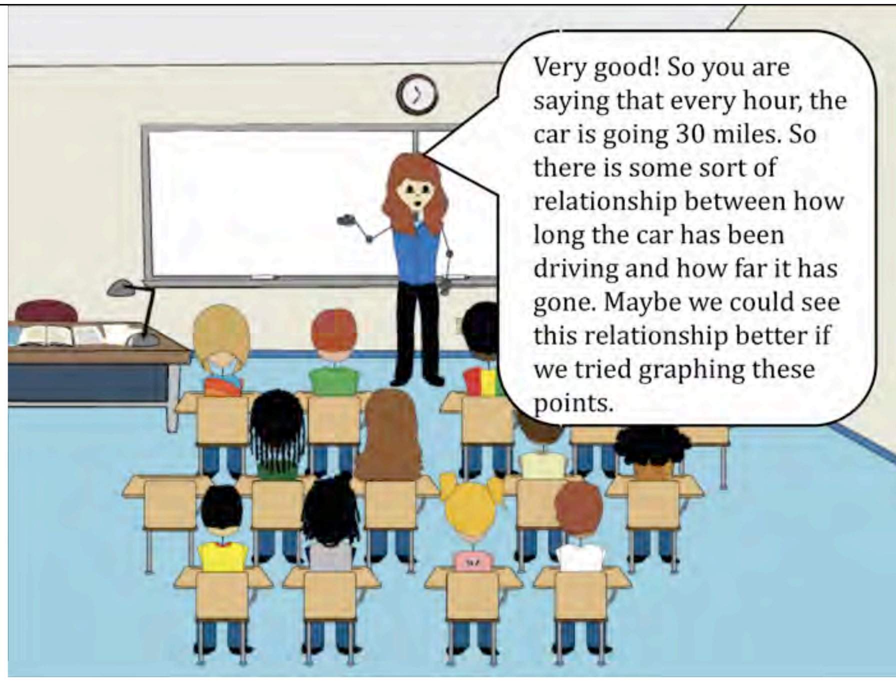


Figure 21. EE-S07-v2: The virtual teacher suggests graphing points help better see the relationship between the two variables in the table.

After revising Slide #7, Ellie and Elliot continued reviewing Slide #8 (see Figure 18), the last slide they created before reviewing. In Slide #8, the virtual teacher was explaining the relationship between the values in the table and the points on the graph. However, they were not content with the explanation when composing this slide.

When they were reviewing Slide #8, they agreed that they needed to emphasize the connection between the two variables in the table and the x and y values on the coordinate plane. They found that the explanation the virtual teacher gave earlier was not clear, and thus deleted all the text in the speech bubble. However, they had difficulty in coming up with a better explanation.

They expected that the virtual teacher would need to make the corresponding relationship explicit between the two variables in the table and x and y value. Ellie typed: “So if the number of hours the car has traveled is our *x*-value and the total distance is our *y*-value,” However, they were still not certain how to address that corresponding relationship when graphing points.

286	Elliot	Yeah. [types] What’s the next slide say[12]?
287	Ellie	There she is like solve X is the number of hours and Y is the total distance traveled. [Elliot: Yeah.] Where’s the point where—yeah, how would we graph or plot the first point on our table or something. And…
288	Elliot	Here, why don’t you type that. If we say the hours it’s like the X value.
289	Ellie	[types] Um, so I don’t know. So if… the number of hours the car has traveled, oops.
290	Elliot	Is our X value.
291	Ellie	Is our… and the total distance is our Y value and I don’t know—what would you—how do you… okay. [pause 5s] I don’t know. We plot that, I don’t want to say like plot the first point.

When thinking about how to graph points with applying the values from the table, Ellie showed her concern about using the word “plot” to represent the graphing of the points. She wasn’t sure that students had known that an ordered pair represents the coordinates of a point, thus knowing how to “plot” a point from an ordered pair (Turn 295). Then Ellie and Elliot decided that after addressing the two variables as *x* and *y* values, the virtual teacher asked students to find a point on

[12] Elliot went on to check Slide #8 they created earlier.

the graph. She asked: ”how could I find where our first point on the graph is? What two numbers should I use?”

291	Ellie	Is our… and the total distance is our Y value and I don’t know—what would you—how do you… okay. [pause 5s] I don’t know. We plot that, I don’t want to say like plot the first point.
292	Interviewer	Why not say that?
293	Ellie	Why not?
294	Interviewer	Yeah.
295	Ellie	I don’t know because I feel like maybe they don’t—maybe they haven’t made the connection that (1,30) would be the point y’know what I mean, like maybe they don’t know that one and 30 go together or I don’t know. It’s hard when you don’t know what the kids know. Um… I [pause 5s] maybe I don’t know, she can plot the first point and say like, what does this point tell me or, or how does this point relate to the table or something.
296	Elliot	I think she should just say something like… I think she should just say something like what would our first-- how could I find where our first point on the graph is?
297	Ellie	Okay.
298	Elliot	[types] Like, maybe like what two numbers should I use? Just like something like that. [pause 8s] Does that look okay? I don’t know, I think they will pick up on that, I don’t think we’ve said anything that’s too shocking to the kids, as long as

		it wasn't too fast or anything. This guy would probably answer it, or girl.

The discussion around Slide #7 and Slide #8, in which Ellie and Elliot were creating, reviewing and revising, shows that they became aware of the need to make transitions between tasks. Specifically, they made efforts to make the connections explicit between the two variables in the table, *x* and *y* values, and the coordinates of points on the graph.

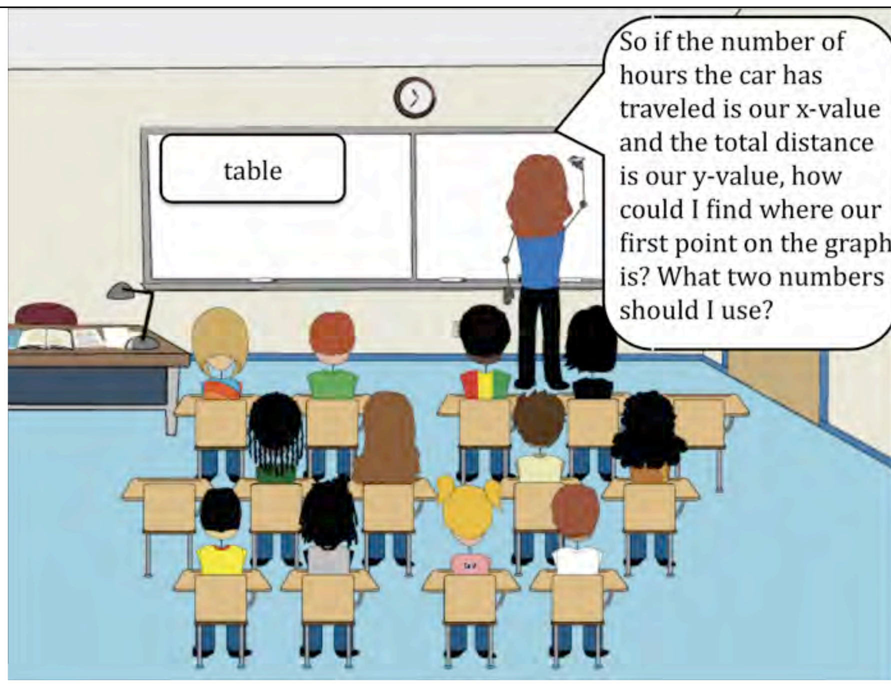


Figure 22. EE-S08-v2: The virtual teacher addresses the relationship between two representations.

After the virtual teacher posed the question in Slide #8, Elliot chose a slide template of view of students as Slide #9. He commented that students would know the answer. He first typed up the answer "1 and 30, maybe?" in a speech bubble, and then suggested that the answer would come from another student who had not talked yet so as to make more students participate in the lesson. He dragged the speech bubble to a student sitting in the second row and added a neutral-speaking expression to his face.

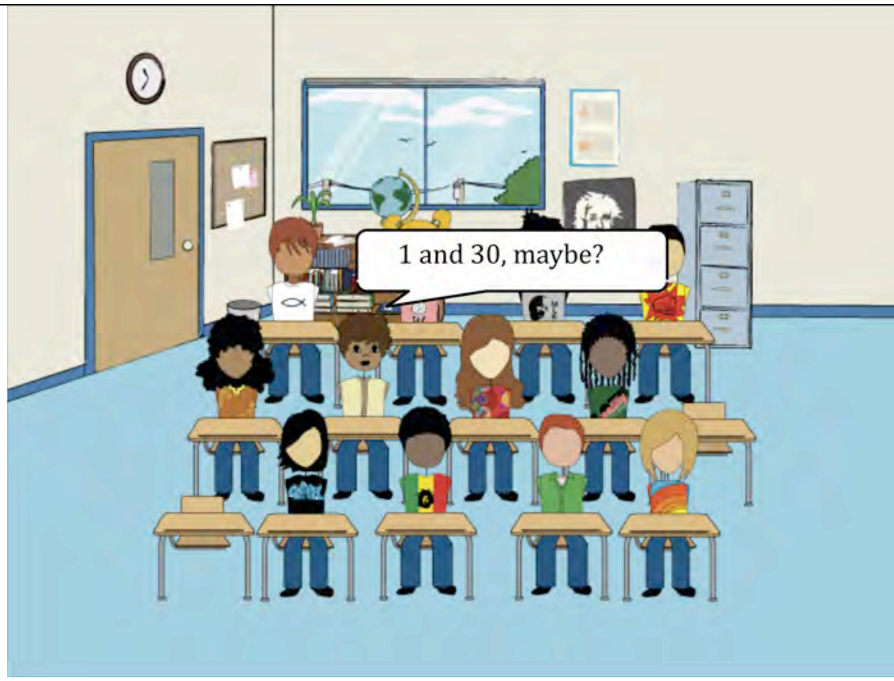


Figure 23. EE-S09: A student, who has not participated in the lesson yet, answers the question.

In the following slide, Slide #10, Elliot had the virtual teacher writing on the right side of the board and comment on the student's answer: "Excellent!" This slide also shows that the virtual teacher was graphing the first point. In doing so, it would help students to better observe the connection between the two variables of the table and the coordinates of points.

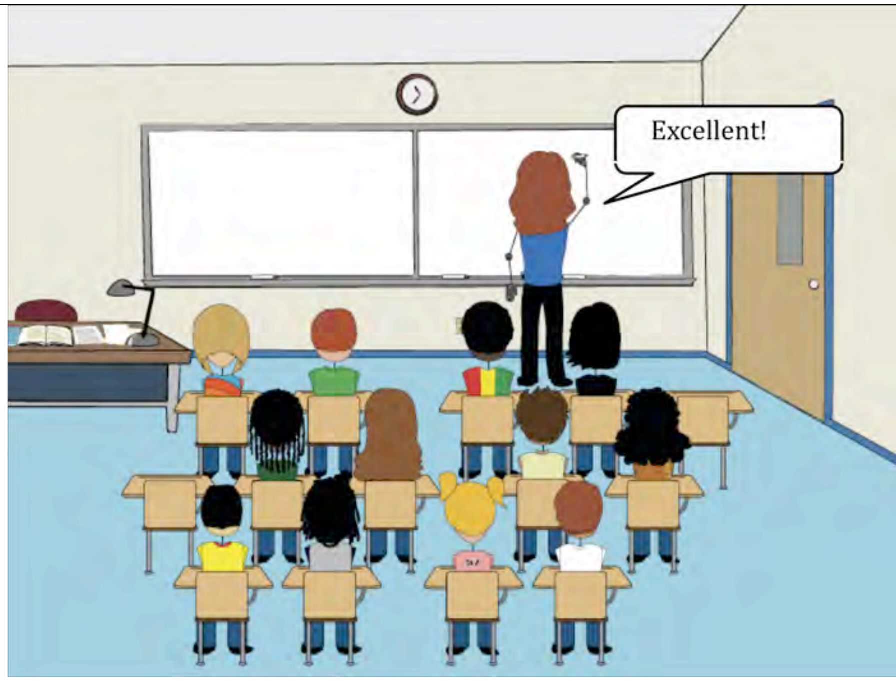


Figure 24. EE-S10: The teacher is graphing.

In Slide #11, the graph was drawn on the right side of the board (see Figure 25). This graph consisted of a point and two numbers marked on *x*- and *y*-axes. A caption box with “table” was on the left side of the board. With both the table and the graph on the board, the virtual teacher asked students to find the relationship between the first row of two columns in the table on the left side of the board, and the first point drawn on the coordinate plane on the right side of the board. Elliot commented that this graphing process would be continued and he used a caption box to indicate this process in the next slide (see Figure 26).

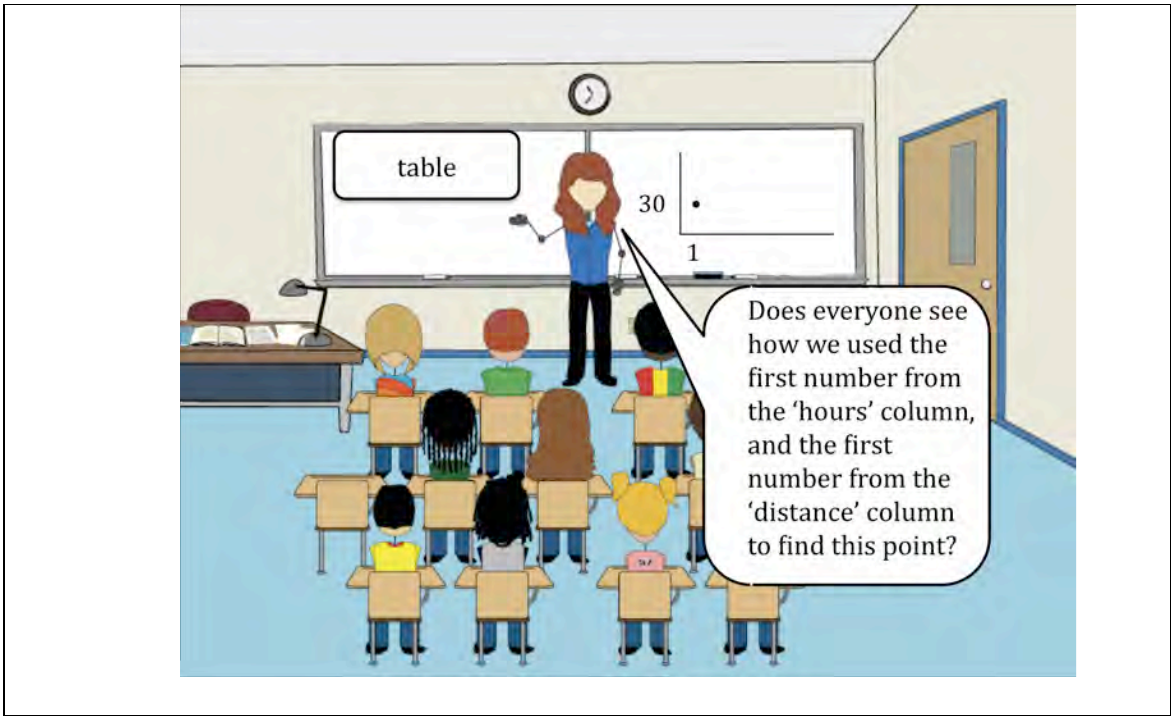


Figure 25. EE-S11: Both the graph and the table are on the board.

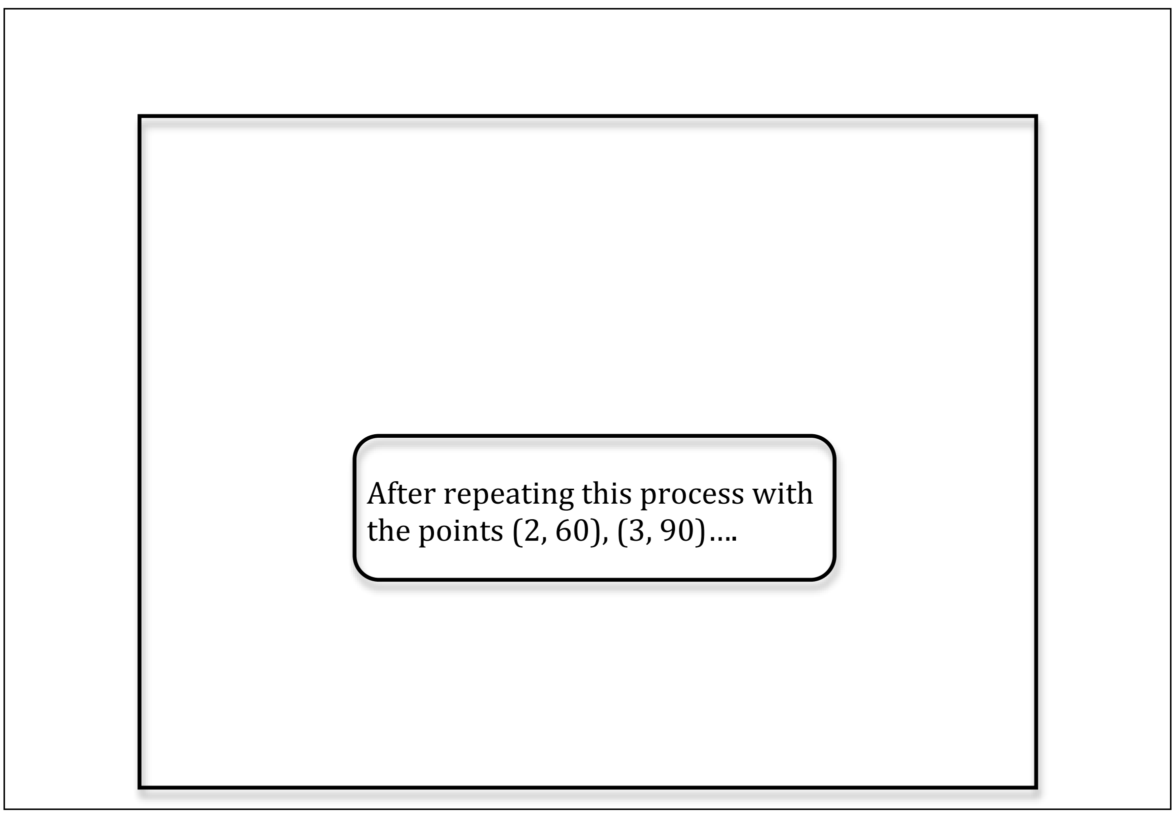


Figure 26. EE-S12: The teacher and students continue graphing points.

Thus far, Ellie and Elliot had spent approximately fifty minutes in composing twelve lesson slides. The interviewer then asked them to review the slides they composed that far to see if they would make any revision. They reviewed their depiction from Slide #6 to Slide #12, for which they had spent approximately thirty minutes thinking of a better way to explain the transition between two representations. They did not make any revision during or after reviewing these lesson slides at this time.

Analytical commentary on Ellie and Elliot's lesson depiction

Differentiating the lesson plan and Depict lesson slides

When Ellie and Elliot were first asked to depict their lesson, they intended to copy their lesson plan. However, after they typed up the first question the virtual teacher would ask, they realized that the teacher should have set up the question by introducing the context of the table on the board and explaining the two columns. Subsequently, they treated their lesson plan created beforehand as a reference when depicting their lesson. They spent time thinking about the teacher's action and the students' possible responses. This shows that the lesson plan could not fully illustrate how the teacher would behave or interact during instruction. The activity of lesson depiction allowed the participants to immerse themselves in the teacher's role and afforded them the opportunity to approximate the practice of teaching.

Attending to the interactions between teacher and students when depicting the lesson

The work of viewing slides afforded Ellie and Elliot the opportunity to attend to the interactions between the teacher and students during instruction. For example, when composing Slide #2, they intended to use the same template as in the previous slide, in which the virtual teacher was present. However, later they realized that there should be students' responses to the teacher's previous question. Hence, they inserted a slide template with the view of students and hypothesized a student's possible response.

Attending to learning resources when depicting the lesson

The activity of viewing slides allowed the pair of participants to examine the learning resources available for students to accomplish instructional tasks. For example, when composing Slide #5 on a new template with a blank board, Ellie and Elliot discussed what question the virtual teacher should use to prompt students to make an inference from the given information. They became aware that the table presented earlier should still be up on the board as a resource for students. Thus, instead of using the new slide template of a blank board, they deleted it and duplicated a previous slide. Viewing the slide they were going to compose helped the pair of participants visualize and examine whether the contextual resources are available for facilitating the students' thinking and learning.

Attending to specific teacher moves when depicting the lesson

Another example also shows that viewing the slides allowed the pair of participants to specifically consider possible teacher moves. When composing Slide #8, in which the virtual teacher was supposed to graph the table on the board, Elliot originally chose a slide template of a teacher writing on the left side of the board. However, when Ellie and Elliot were working on what the teacher would say or do in the slide, they realized that the table should still be on the left side of the board and the virtual teacher would need to write or graph on the other side. In Slide #8 in which the virtual teacher was going to make the connection between the table and the graph, the pair of teachers thus needed to consider the availability of the table in order for the students to have the table as a resource to graph the points on a coordinate plane.

Reviewing lesson slides helps to examine and revise instructional moves

Reviewing slides is another important feature in *Depict* that allowed the pair of participants to examine and modify their instructional moves. When Ellie and Elliot were stuck at thinking about how to make a transition from reading the table to graphing it, they reviewed the slides from the beginning. In Slide #1 in which the virtual teacher was introducing the table, they realized they needed to explain the two columns of the table respectively. The virtual teacher would thus help students better see the relationship between the two variables. This move might also be beneficial thereafter, when students were making the connection between the two variables and an ordered pair of a coordinate point.

As the participants continued reviewing the slides, they made major revisions on those in which the virtual teacher explained the transition between two tasks. In the original Slide #7, the virtual teacher was proposing that students graph the table without any explanation of reason or connection between the table and graph. In the original Slide #8, the virtual teacher was giving direct instruction on how to transfer the numbers from the table to the coordinates of points on a graph. However, when reviewing these slides, they realized that what the virtual teacher said in Slide #7 and Slide #8 was not explicit enough to help students understand the relationship between the two variables in the table and the ordered pairs of the coordinate points.

In the revised slides, the virtual teacher first suggested a certain relationship between the two variables in the table and proposed that graphing may clarify the relationship. The virtual teacher then addressed the relationship between the two variables and *x*-and *y*- values and asked students to identify the first point on the coordinate plane.

Making transitions between tasks when depicting the lesson

Although Ellie and Elliot had difficulty making the connection between the table and the graph when depicting the lesson, through reviewing and revising the slides, the participants were able to made a transition between two tasks. They explicitly established relationship between two variables and *x*- and *y*- values apparent to the students. Such transitions had not been addressed in their lesson plan. And it was challenging for them when they were depicting the lesson. Reviewing slides helped them specify the teacher's moves in making such a transition explicit for the students, so as to help them better understand the connection between two representations.

Anticipating students' verbal and nonverbal reactions

In addition to attending to the teacher's actions, Ellie and Elliot anticipated students' possible verbal and nonverbal reactions. Such anticipation had been absent in their lesson plan. When they first anticipated students' responses in Slide #2, they only attended to one student, who gave a correct answer. In Slide # 4, in which students' responses were expected after the teacher's question, two students were attended to. One student gave the answer and the other student who answered the previous question also raised his hand, indicating he would also know the answer. In Slide #6 in which students had to make an inference about information beyond what is given, more students were involved. In addition to one student who gave the correct answer, some students showed uncertainty in their expressions. Furthermore, time was given for students to think about the question. In Slide #9, a student, who was responding a question, was noted as one who had yet not participated.

Lesson depiction allowed the participants to attend to instructional issues that they had not considered when planning the lesson in text. Through interacting with *Depict*, viewing or reviewing slides, they specified the teacher's moves. They made the virtual teacher set up the question by providing the context of the given problem and explaining the given information. They intended to help students better understand the question and answer it. They also provided time as a resource for student thinking. They attended to consistent board content, so the information previously presented on the board could serve as a resource for a later task. The activity of lesson depiction also facilitated this pair of teachers' thinking about making a connection between two tasks. In particular, they made efforts in thinking how to make the relationship between two representations explicit and comprehensible to students. They also made such relationship verbally and visually accessible to students. Finally, they were aware of the issue of students' participation in class. Not only did they attend to individual students, but also to multiple students at the same time.

Lesson depiction allowed this pair of participants to attend to issues of making resources available to students. It also made them re-examine the goals of tasks they intended for students to achieve by specifying the teacher's actions. Moreover, it allowed them to identify the operations that students would need to perform in order to accomplish the tasks.

Case #2: Pamela and Sienna's work

In Pamela and Sienna's work, four tasks from their lesson plan were anticipated through lesson slides in *Depict*. They implemented these four tasks with eight lesson slides. They provided a real-life problem and intended for students to represent the problem in a table and then graph the table. However, their lesson plan was not very articulated and the mathematics problem in the lesson was not appropriately chosen regarding its mathematical sophistication.

Anticipating Task #1

In Sienna and Pamela's lesson plan, they wrote:

Discuss issue of walking up stairs at a constant pace (3 stairs in 3 seconds) Ask how long it would take to walk up 100 stairs

Figure 27. The first task in Pamela and Sienna's lesson plan.

It can be assumed that the goal of the task is to ask students to predict how long it would take to walk up 100 stairs. The resource is the given information that one walks up 3 stairs in 3 seconds. It is not clear in their text how the teacher will discuss the issue regarding walking up stairs and what kinds of operations that students would need to do in order to answer the question regarding the time taken for walking up 100 stairs.

When beginning to compose the first lesson slide, Sienna and Pamela seemed to intend to copy what was written on their lesson plan. Sienna first had the virtual teacher introduce the day's topic: "Today we are going to be discussing slope, but first we're going to relate this to walking up stairs at a constant pace." Then based on their text, the teacher was supposed to ask the question: "how long it would take to walk up 100 stairs?" Sienna typed in the second speech bubble on Slide #1: "How long would it take to walk up 100 stairs?" When this pair of participants viewed this slide, they realized that they needed to include many details that were not included in their lesson plan.

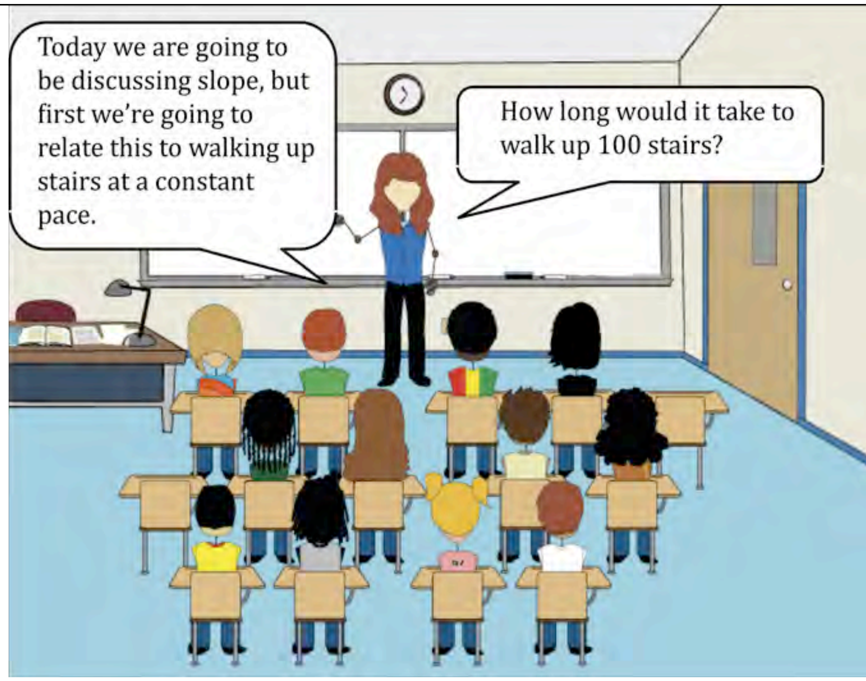


Figure 28. PS-S01-v1: The virtual teacher asks a question without given information.

Then they modified the virtual teacher's question to read: "how long would it take to walk up 100 stairs if you walk up one stair every second?" Sienna and Pamela realized that the question posed to students should include given information, so that students would be able to answer.

In the first version of the question: "How long would it take to walk up 100 stairs?" it did not include any given information and it is impossible to answer. It was not until Sienna and Pamela viewed the slide that they noticed that the question needed to include the given information.

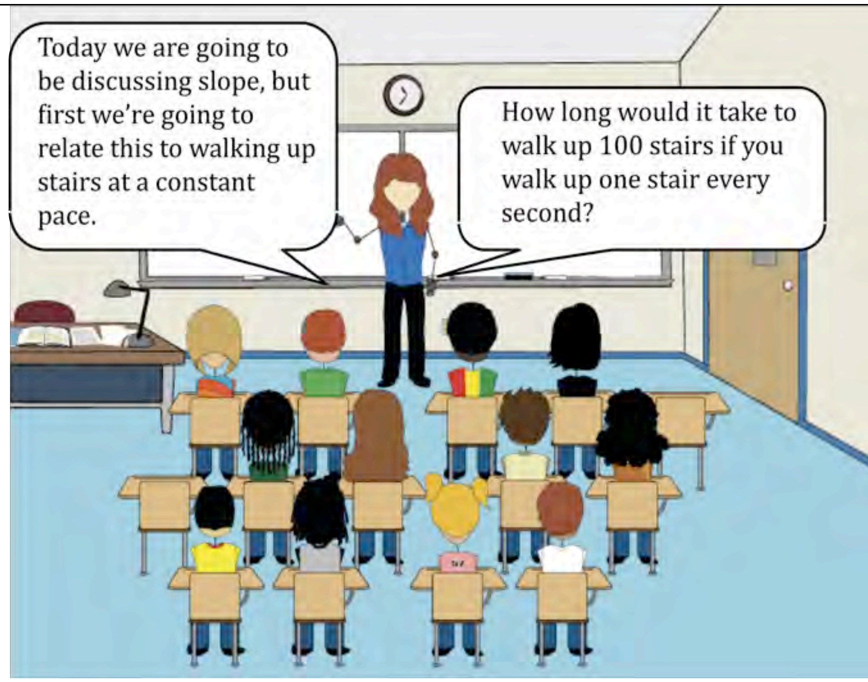


Figure 29. PS-S01-v2: The virtual teacher asks the question with given information.

After finishing Slide #1, Sienna proposed to have some responses from students. She suggested that students might not be able to answer the question, but could make a deduction from the given information[13]. Further, Sienna suggested that the virtual teacher could later ask a student to graph the points using the numbers from other's responses.

Instead of only anticipating correct answers from students, Sienna proposed what students might be and might not be able to do: Students might be unable to answer the question right away, but they might be able to deduce from the given

[13] The pair's expectation on students' capability on the assigned task was low. The analysis here intends to identify how lesson depiction facilitates prospective teachers' attention to instructional details. The mathematical sophistication of the assigned task, the prospective teachers' perception of students' ability or the quality of the text lesson plan are not the foci of this piece of analysis.

information. She also considered the continuity and relativity of the two consecutive tasks that students' initial responses could be taken as a resource for graphing later.

When anticipating students' responses, Pamela selected a slide template with the view of students as Slide#2. She then typed up a response from a student sitting in the second row. When thinking about what expression this student might have, Pamela suggested that this student would have a "duh" expression. However, they could not find any expression in *Depict* that corresponded to what they wanted to show. As a result, Pamela chose a male-neutral expression and described the student's thought in a caption box. In the caption box, Sienna typed: "Student is thinking 'duh, this is obvious'."

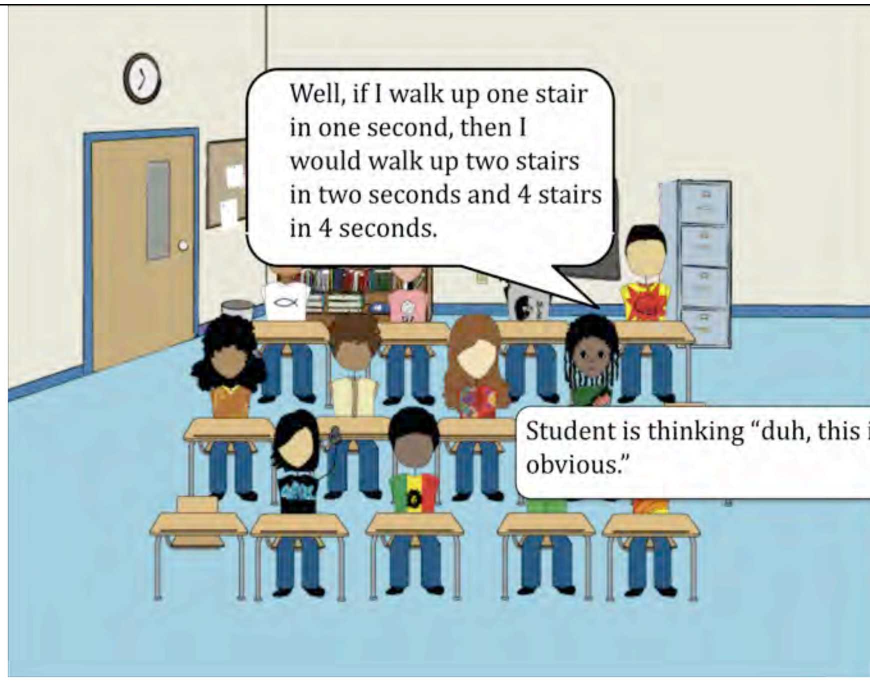


Figure 30. PS-S02-v1: The student was thinking that the question was too easy.

Later, Pamela and Sienna agreed that there should be other possible responses from students. Pamela suggested that there be a student who might not understand the previous student's answer. And Sienna suggested the thought about the straightforward nature of the question could come from another student.

The student's thought about the nature of the question was originally assigned to the student who answered the question. However, when the pair viewed the caption box containing "duh" response on the slide, Sienna suggested this response should come from another student. Hence, Pamela dragged the caption box to the bottom right corner of Slide#2, indicating the first student from right in the first row was thinking that. And she moved the mouse over to the left side of the slide and suggested that "… we can also have someone from over here, that's kinda say, 'well I don't understand why—where's he getting these from?'" A question was then posed from the first student from left in the first row: "why did you skip three?" This student also had a female-confused expression and was raising her left hand. The student who thought the question too easy had a male-bored expression. Students' verbal and nonverbal responses in Slide#2 to the virtual teacher's question were not planned in the text.

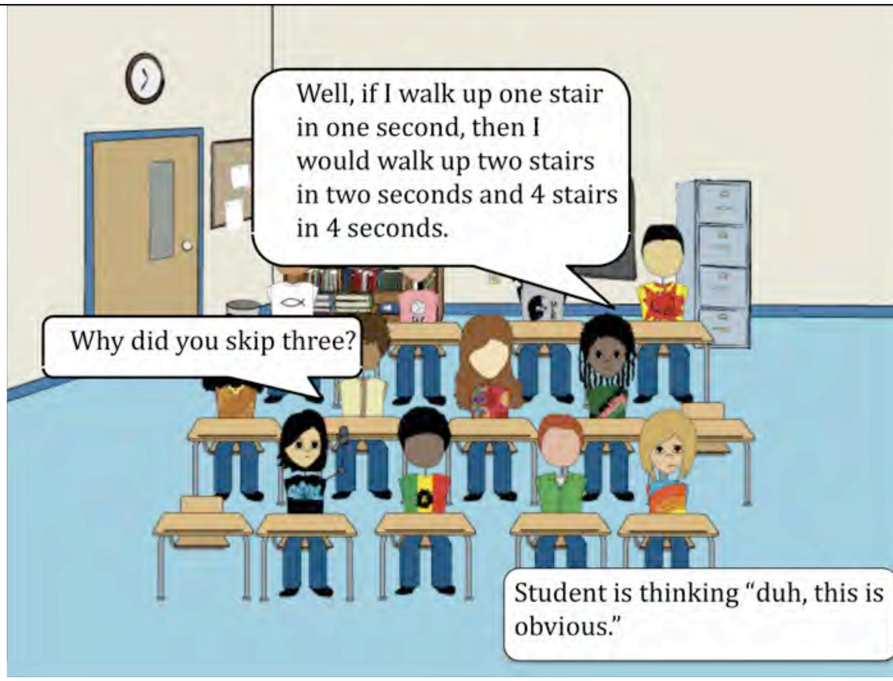


Figure 31. PS-S02-v2: Multiple students think and act differently at the same moment.

In Slide#2, the pair of participants involved three students in the class and they also attended to the interactions among the students. These students had diverse verbal or non-verbal responses. One of the students was able to explain his thinking process aloud but could not answer the question. Another student was thinking the question was too easy. One other student did not understand his classmate's answer and expressed her confusion.

Analytical commentary on Task #1

The first task in the lesson plan asked students to predict the time spent on walking up 100 stairs. When writing the plan, the pair of participants had not attended to any resources and operations that students would need to implement the task. However, when depicting the lesson, resources and operations became apparent to them. For example, the virtual teacher posed the question:" how long would it take to walk up 100 stairs if you walk up one stair every second?" The given information of one stair per second was not explicit in the lesson plan. When composing the slide, Sienna and Pamela did not provide this given information either; it was not until they read what they initially typed that they realized what they needed to include.

Students' verbal and nonverbal responses became apparent to the pair in lesson depiction. In Slide #2, three students were involved in different thinking about the teacher's question. One shared his thinking process but did not necessarily answer the question. Another thought the question was easy and thus looked bored. A third student could not follow her classmate's answer and was confused. The participants anticipated students' thinking along different lines. While some are thinking about how to answer the question, others are thinking about the nature of the question itself.

Anticipating Task #2

The second task in Sienna and Pamela's lesson plan involved having students draw a table on the board to show sets of points that refer to the numbers of steps and the time taken. The goal of this task is to use a table to represent the relationship between the two variables. The resource was not explicitly mentioned. The pair did not specify what kinds of operations students would need to perform in the task.

Suggest having one student write a table format of the points. The points here are (0,0), (1,1), (2,2), (3,3) which are # of steps and time in seconds.

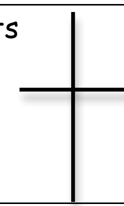


Figure 32. The second task in Pamela and Sienna's text-based lesson plan.

When depicting the lesson, Sienna referred to the task in the text and suggested the virtual teacher ask a student to represent the previous answer in a table. She further commented that this task of representing the sets of numbers in a table would help students better understand the question of walking up stairs in a constant pace.

202	Pamela	Okay so can we go onto the next slide and have the teacher make some comments.
203	Sienna	Yeah then she can say why doesn't someone come up here and put these in a table so then maybe they would under—they would connect it a little bit better to what they hopefully would have previously done.

Figure 33. Sienna suggests the task help students better understand the question.

In Slide#3 (see Figure 34), the virtual teacher asks the student who answered the previous question in Slide#2 to come to the board and present his answers in a table format. They named the student Bob.

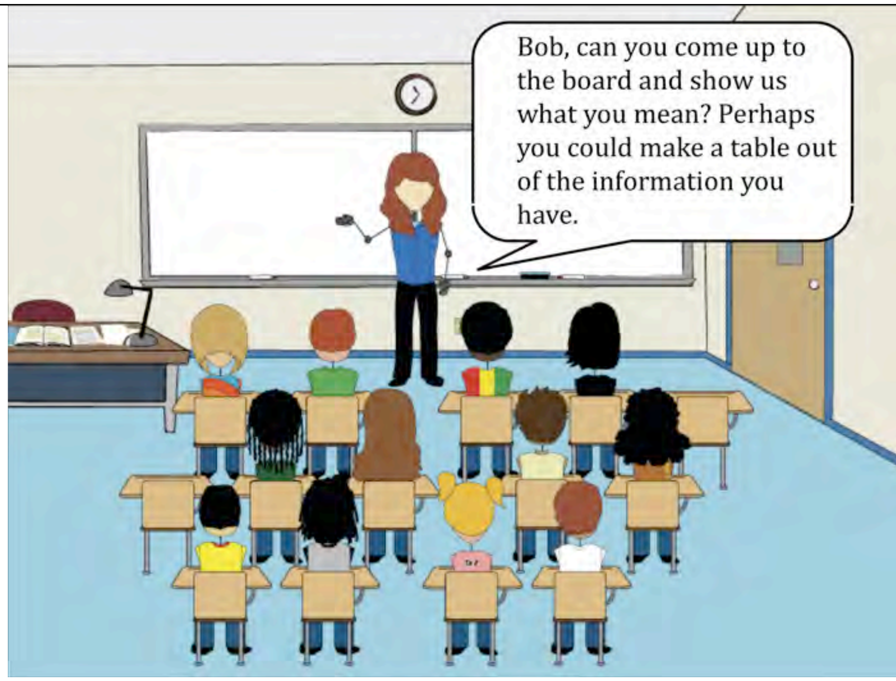


Figure 34. PS-S03: The virtual teacher asks the student to present his earlier answer in a table.

In the next slide, this pair intended to show the boardwork that Bob had done. Pamela chose a slide template with a blank board as Slide#4. She then opened the drawing tool and drew a big cross to represent a double entry table. Pamela typed three pairs of numbers in the two columns in which the numbers obtained from Bob's previous answer. Sienna reminded her partner that she needed to write "stairs" and "seconds" at the top of each column. Then Sienna typed, "seconds" and "stairs" in the top left column and the top right column respectively. After the headings were typed in the table, Pamela asked whether *x*- and *y*-values should be reversed in the two columns. However, they did not have other resources to confirm which way was correct. They decided to leave them as what Sienna had typed, which was the *x*-value on the left and the *y*-value on the right. Then they attached the table to the board.

Sienna described Bob's action in a caption box that Bob drew the table without talking. Sienna and Pamela explained that high school students usually do what they are asked to do and do not make more efforts unless they are asked to do so. They also commented that Bob thought that everyone else should also understand what he had written on the board, so there was no need to give further explanations.

A speech bubble in the bottom right corner coming from the virtual teacher indicates that she appreciated Bob's work. When viewing this slide, Pamela suggested that the virtual teacher should ask Bob to further explain his answer and respond to Susie's earlier confusion. Sienna then typed up the virtual teacher's question to Bob and described the teacher's action in a caption box. This teacher's move had not been included in their lesson plan.

Before the pair of participants went on to create the next slide, they viewed the current one. Pamela proposed that there should be a description about Bob's returning to his seat after drawing the table (see Figure 35).

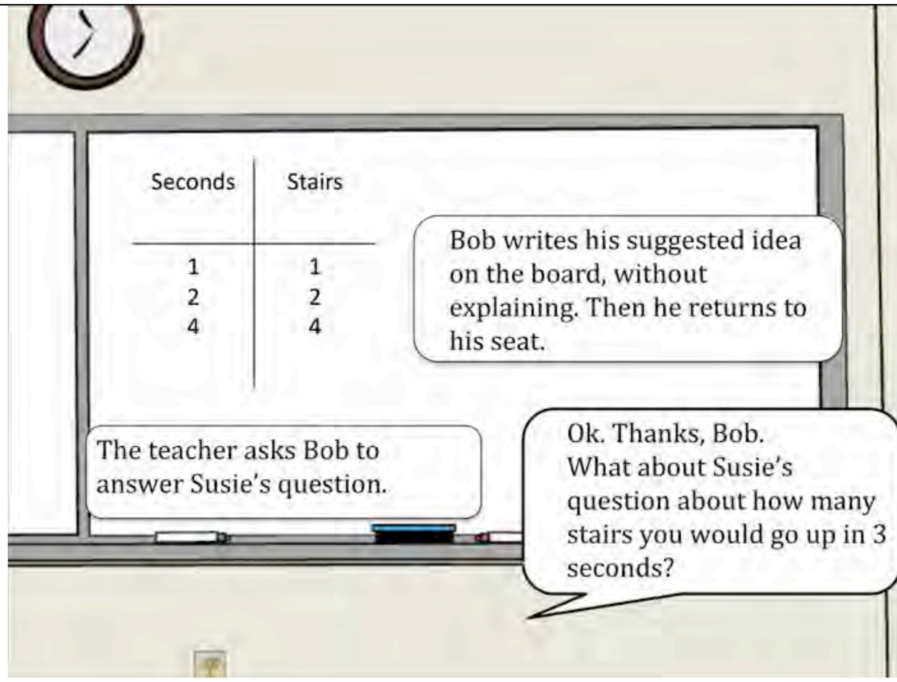


Figure 35. PS-S04: Bob presents his work on the board.

In this slide, the virtual teacher's and Bob's actions were described explicitly in caption boxes. First, Bob came up to the board to draw a double entry table to represent the relationship between the time taken and the total steps walked up. However, he returned to his seat without explaining his work on the board. The virtual teacher acknowledged Bob's work and then prompted Bob to explain more in responding to Susie's question.

In the next slide, Sienna and Pamela both agreed to have a slide template with the class of students because Bob had just returned to his seat and he had to respond to the teacher's request. Pamela commented that Bob would not be able to explain the question well, because a typical high school student would think the answer is obvious and could not think of any further explanation. As a result, Bob would respond: "It works for 3 too, but you don't need to include every number."

313	Pamela	Okay. He's probably not going to be the best at explaining it so he's probably just going to say, I don't know, that's just how it works? I mean, I think that would be a typical response in a classroom from a kid, it's just-- well it just works.
314	Sienna	Mmhmm.
315	Pamela	"Just trust me."

Because Bob did not provide further explanation of his answer, Sienna suggested that Susie would still be confused and someone else in the class could help in explaining to Susie. Then Pamela put a confused expression on Susie' face. Another student, who sat in the third row and later was given an excited expression, made further explanation regarding the pattern between the time taken and the steps.

After the student's explanation, a speech bubble in the bottom right corner contains the virtual teacher's question: "Does that make sense to everyone?" Pamela then suggested that after the explanation, other students had "an understanding of where the data points are coming from or they see the pattern at least." This comment shows that Pamela anticipated the goal that the students would need to accomplish in the current task. This goal had not been specified in the pair's lesson plan.

A caption box beside the teacher's question then described that the students in the class would have a better understanding of the relationship between the two variables after the student' further elaboration of the table. In Slide #5, it illustrates the interactions among the students in the lesson. For example, Bob gave an answer but could not provide a clearer explanation. Susie was confused by Bob's unclear answer. Then another girl jumped in helping explaining the relationship between the two variables.

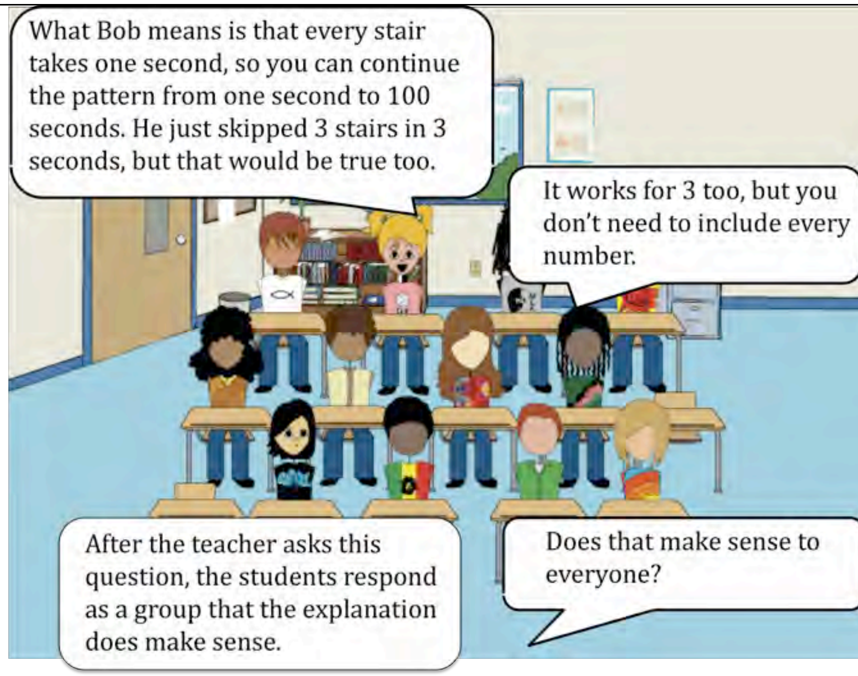


Figure 36. PS-S05-v1: Multiple students are involved in the lesson.

Analytical commentary on Task #2

The second task in the pair's lesson plan was to have students present sets of order pairs of two variables in a table. However, the goal of the task had not been clearly stated. When depicting this lesson, Sienna explicitly stated that the representation of a table helps students better identify the relationship between two variables, thus understanding the stair problem. Hence, through the representation of the task in *Depict*, the pair of participants identified the operations.

The activity of lesson depiction encouraged the participants to individualize students and anticipate different students' possible responses. For example, in Slide #3 (see Figure 34), the student, who had answered the question earlier, was called to the board by his name (Bob) to draw a table. Other students were also identified by name. Individualizing students allows the participants to see students as more than a class. It then allows the participants to anticipate that students may have diverse reactions or thoughts. They had not individualized students in their lesson plan.

Seeing students as individuals allowed the pair to elaborate their characteristics. In Slide#4 (see Figure 35), they anticipated that Bob would draw a table on the board without explaining it. The pair agreed that a typical high school student would not make more effort unless asked to.

The activity of lesson depiction provided this pair of participants a context to discuss mathematics. When drawing a table as a student's board work, the pair discussed where to place the two variables as *x*- and *y*-values in the two columns. It showed that specifying board content on lesson slides provides an opportunity for participants to discuss mathematics. The discussion revealed a need for additional resources to push the participants to articulate the mathematics in their lesson. The creation and visualization of the board work in *Depict* provides a context for examining the mathematics, but such supports were absent in the text-based format of lesson plan.

The pair of participants developed a series of teacher-student interactions in lesson depiction that were not noted in their lesson plan. For example, in Slide #4, the virtual teacher asked Bob to elaborate his answer. This move resulted from Susie's confusion from a previous slide.

Reviewing lesson slides

Sienna and Pamela were prompted to review their lesson slides from the beginning after they implemented the second task. They did not make any comments or revisions until Slide #5. This slide includes several students interacting simultaneously. When the pair was reviewing this slide, Sienna commented that because there were multiple dialogues in the same slide, a caption box was needed to describe the sequential relationship of the students' involvement. In addition, a student who was involved in the dialogue was identified with a name.

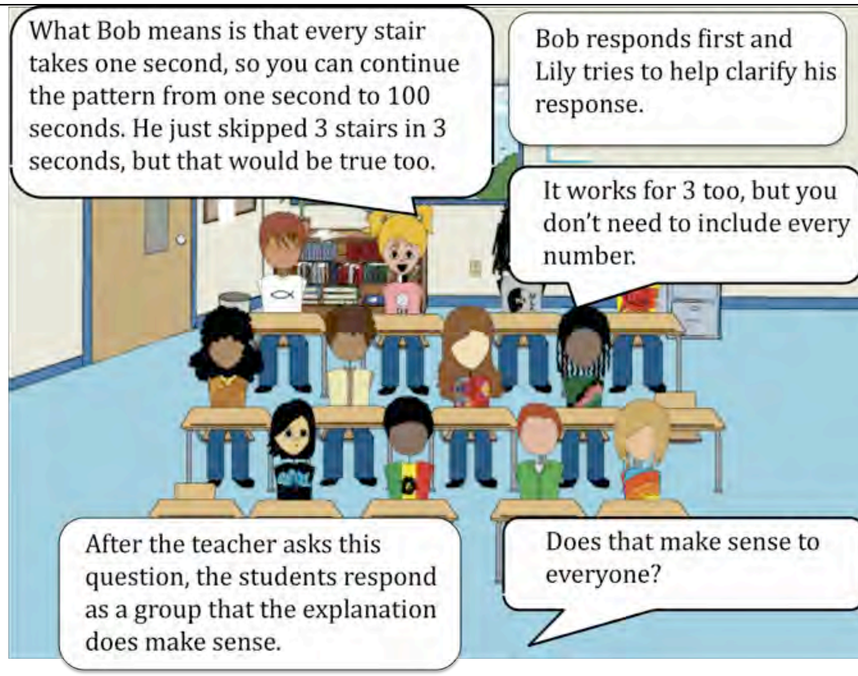


Figure 37. PS-S05-v2: A caption box in the upper right corner is added to illustrate the sequential relationship of the students' involvement.

Anticipating Task 3

The third task in Sienna and Pamela's lesson plan was to graph the table. The activities in this task involve graphing points and connecting them in a line (see the figure below). However, the goal of this task was not clearly stated. The resources for graphing are sets of numbers from a previous answer, students' prior knowledge of graphing and classmates' cooperative work. They did not specify the operations required in the task.

Ask another student to plot these points on a graph with class help and draw a line connecting these points. This will check their prior knowledge.

Figure 38. The third task in Pamela and Sienna's lesson plan.

The pair created a slide template with the teacher standing at the center facing students as Slide #6. The virtual teacher said:" Maybe it would help[14] to see this on a graph. Does anyone want to come up and show how to graph the points in Bob's table?" The virtual teacher explicitly suggested that graphing points helps students to see the relationship between the two variables of time and the amount of stairs. This is also the goal of the graphing task.

Sienna suggested there be a student who would voluntarily graph the points. And Pamela agreed and proposed that Susie, the girl who was confused, would know how to graph the points. Pamela further suggested that even though Susie was still confused, she could better see the pattern of change between the two variables through graphing.

375	Pamela	Oh yeah, we can have like um, Susie like oh, I know this, y'know, like at least she knows how to do that but she's still confused and she goes up to do it she'll maybe start to see the pattern the one stair every second two stairs every two seconds, so she can say oh, well I know how to graph.

In Slide#6, Susie raised her hand and said she knew how to graph the points from Bob's table (see Figure 39). A caption box described that Susie was not frustrated anymore.

[14] Sienna later revised it to" Maybe it would be helpful to see…"

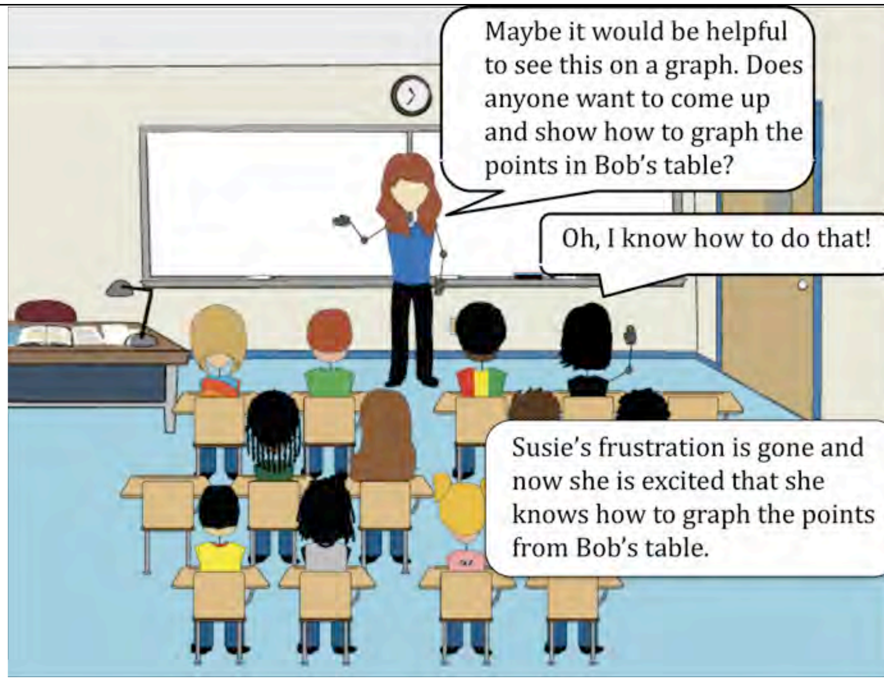


Figure 39. PS-S06-v1: Susie knows how to graph and she could better see the change of the two variables through graphing.

In the next slide, the participants intended to show the board work that Susie made. Pamela selected a slide template with a blank board as Slide#7. After viewing the template, Pamela commented: ”Okay so we had the white—the board from before which was the points, which would be on the left, right?” She realized that in order for Susie to graph points, the sets of numbers from the table needed to be on the left hand side of the board as a resource for her.

Pamela started graphing Susie's board work on the right side of the board in the drawing tool. She first sketched two segments perpendicular to each other in order to represent two axes on a coordinate plane. Then she put four roughly equally distributed hash marks on each axis. She then put three coordinate points on the plane, at the positions of (1,1), (2,2), and (4,4). A caption box described Susie's actions of graphing points and returning to her seat.

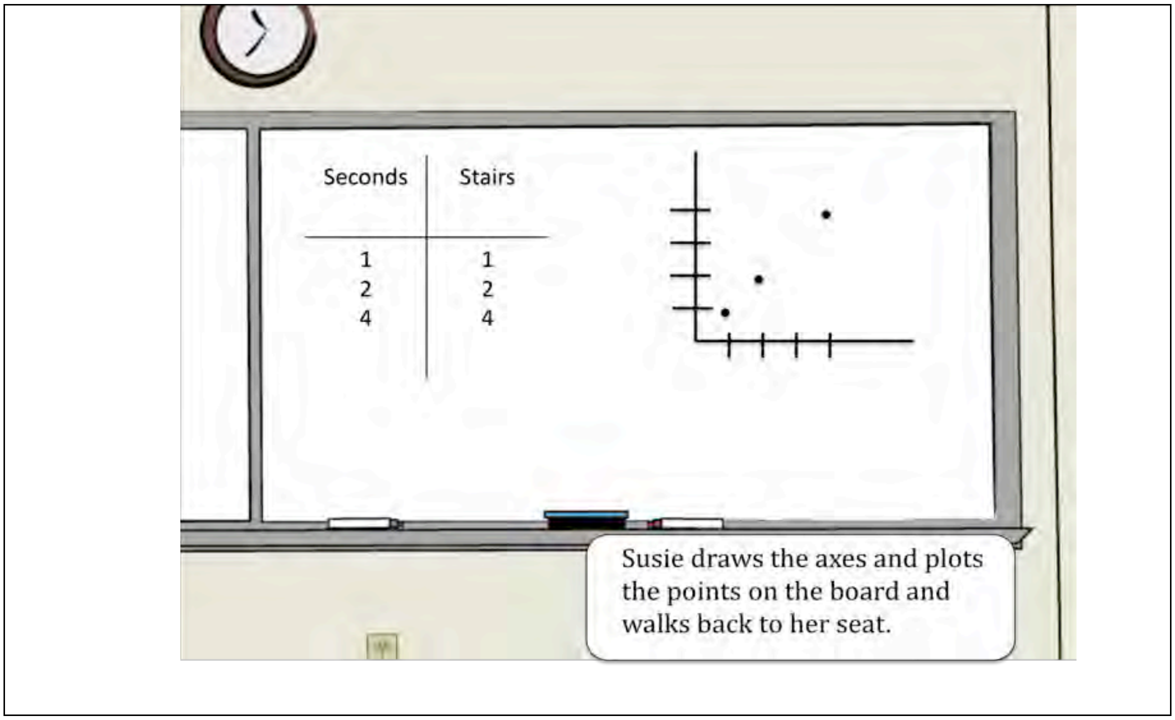


Figure 40. PS-S07: A caption box describes the student's actions.

Analytical commentary on Task #3

The third task was to ask students to graph points from the table presented earlier. However, the goal was not stated in the pair's lesson plan. When depicting the lesson, the pair explicitly identified that the goal of graphing points from a table is to help students see the relationship of two variables. Hence, lesson depiction afforded the pair opportunities to identify the goal of their intended task. In this case, the goal was to connect what had been done previously. When planning the lesson in text, they only considered activities, and did not make the connection between two adjacent tasks. Lesson depiction allowed the participants to see the tasks as connected.

The activity of lesson depiction allowed participants to anticipate students' work and allowed them to examine whether they had provided resources for students to accomplish the task. For example, when composing Slide#7 in which a student was supposed to draw a graph on the board, the pair of teachers knew the table presented earlier should be on the left side of the board as a resource for the current task.

Anticipating Task #4

The fourth task in Sienna and Pamela's text-based lesson plan was to observe patterns from the graph. The goal of this task is to have students recognize that the two variables change at the same rate. The resource available for students is the table and the graph on the board. In their text, the pair intended for the teacher to point to both representations on the board, to help students to observe the constant rate of change. However, it is not mentioned what kinds of operations students need to perform to make such observation.

> Ask: What do notice about how the time change (how many seconds have passed) as you take additional steps on the stairs? As one variable (point to graph & table) gets bigger, the other gets bigger at the same rate, so you aren't speeding up and slowing down. This is a positive slope.

Figure 41. The fourth task in Pamela and Sienna's lesson plan.

After the pair finished composing Slide #7 in which a student came up to the board and graphed points, they discussed how to make students recognize the pattern between the two variables from the current graph. Sienna proposed to have the teacher or a student connect the three points in a line, so students would identify that the point (3,3) is on the line too. Later, however, they reflected on the goal of the graphing points, which is to have students observe the relationship between the two variables in the table and the graph. They noted that it is not important whether the line was drawn. They indicated that students need to notice the pattern that as the time increases and it gets farther on the *x*-axis, the other variable increases on the *y*-axis.

When they identified the operation that students were expected to perform, which was to observe the two variables increase accordingly on the *x*-and *y*-axes, they found out that there were no labels on the axes for students to refer to. Therefore, Sienna proposed to have the virtual teacher write “seconds” and “stairs” on the two axes in the following slide.

Pamela selected a slide template with teacher standing at the center facing students as Slide#8. Then Sienna went into the drawing tool to label the two axes with “stairs” and “seconds.” When Sienna was doing so, Pamela further suggested to label “x” and “y” on the two axes, because, she argued, students commonly confuse the *x*-axis and *y*-axis. After amending the graph in the drawing tool and attaching it to the board, Sienna made a caption box indicating that the virtual teacher would label the two axes and remind students the importance of labeling them.

When considering what the virtual teacher would say next, Pamela pointed to the lesson plan and suggested that the virtual teacher would ask students for what they had noticed about the time change in relation to the distance change. Thus Sienna typed up in a speech bubble: ”What do you notice about the amount of stairs we’ve gone up as more time passes?” Pamela then suggested a student’ response could come from one who had not yet participated in class. They anticipated that this student would observe that the points on the graph formed a straight line. This was based on the pair’s earlier discussion that neither students nor the virtual teacher had to draw the line connecting the points on the graph, but students would need to identify the pattern of change between two variables. Later, the virtual teacher commented on the student's response with further elaboration that the change of two variables is constant.

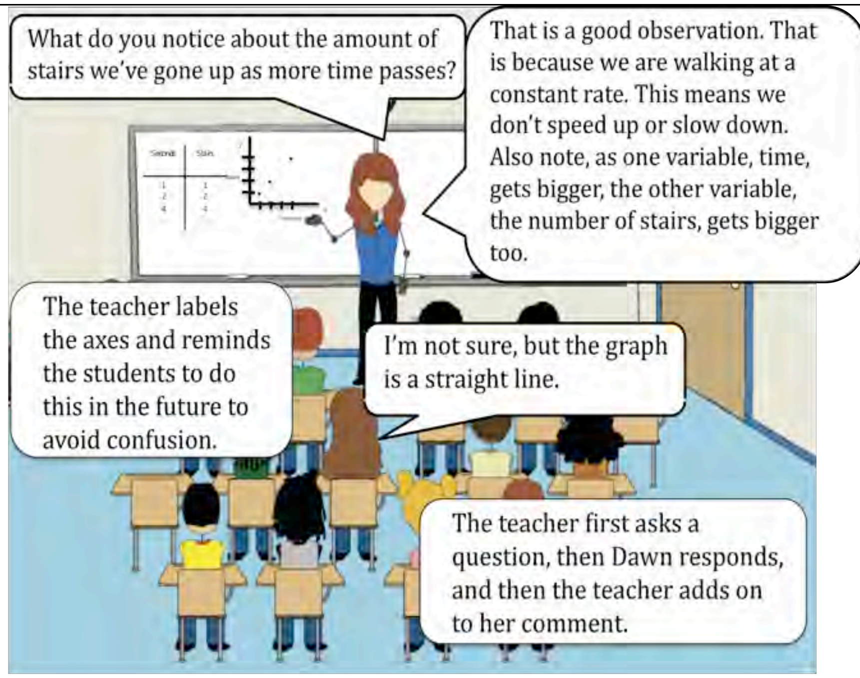


Figure 42. PS-S08: The virtual teacher reminds students to label the two axes. A student who had not yet participated answers the question.

Analytical commentary on Task #4

The activity of lesson depiction encouraged the participants to examine the goal of the intended task and identify needed and relevant instructional moves. When discussing whether there was a need to have a student or the virtual teacher draw a line connecting points on the graph, the pair reflected on the goal of the task: to have students observe the relationship between two variables. Hence, they decided that it was not critical to draw a line connecting existing points on the graph. Besides, the pair also noted that the operation that students would need to perform was to observe the pattern that as one variable increases on *x*-axis, the other variable increases as well.

The activity of lesson depiction prompted the participants to examine the resources they had made available to students. After determining the operations that students might need to perform as identifying the constant increase pattern of two variables, the participants realized that there were no labels on the two axes for students to refer to were they to make the observation regarding two variables. Hence, in the next slide, Slide #8, the pair had the virtual teacher label the axes and remind students to do so. In addition, when labeling the two axes with “seconds” and “stairs”, Pamela further suggested labeling with “x” and “y.” She recognized that students commonly confuse the *x*-axis and *y*-axis. This possible confusion was not recognized in their lesson plan or when they started depicting the slide. It is only when they had the coordinate graph visible on the board that they identified a key concept about which students might get confused.

The consideration of the sequential classroom interactions helped the participants re-examine their earlier instructional moves. When the pair made the coordinate plane, they had not labeled the two axes. They did not become aware of the omission until they were considering the following events. As a result, they turned this omission into a virtual teacher’s reminder to students of the importance of labeling the axes. This suggests that the activity of lesson depiction allowed participants to see the lesson sequentially and thus helping them to examine issues in instruction that they had not been previously aware of.

The activity of lesson depiction allowed the pair of participants to attend to different individual students. For example, when anticipating students' possible responses after the virtual teacher's question in Slide#8, the pair proposed to have a student who had not yet participated in the class answer the question.

Analytical commentary on Pamela and Sienna's lesson depiction

Differentiating the lesson plan and Depict lesson slides

Similar to other participants, Pamela and Sienna intended to copy their lesson plan when asked to depict their lesson. They copied the first question the virtual teacher would ask on the lesson slide. However, after typing it up in a speech bubble, they realized that they had not provided enough given information for students to complete the task. Consequently, they included more information so that students could answer the question. This instance seems to suggest that even though the lesson plan had guiding questions that prompted the participants to attend to teacher, students and mathematics, the participants had not been completely aware of detailed instructional issues. Depicting the lesson seemed to help them become aware of some details previously omitted about instruction in their planned lesson.

Pamela and Sienna attended to other instructional details in their depicting of the lesson that they had not considered in their lesson plan. I will now illustrate these details in the following sections.

Individualizing students

The pair of participants saw students as individuals by naming them. For example, in Slide#3, the virtual teacher asked a student, named Bob, who answered the previous question to present his answer on the board. In later slides, other students were also identified by names. In addition, in Slide#8, a student who they noted that had not yet participated in class, answered the question. Individualizing students seems to help the participants to anticipate that students may have diverse thoughts or responses. It also appears to help the participants to anticipate the interactions among students.

Attending to students' verbal and nonverbal reactions

This pair of participants anticipated students' possible verbal and nonverbal reactions when depicting their lesson. Such anticipation was not included in their lesson plan. For example, in Slide #2, three students were involved verbally or nonverbally in responding to the virtual teacher's earlier question. While a student shared his thinking process aloud, another student was confused and questioned his classmate's answer. A third student was bored with the thought that the question was too easy for him.

Elaborating the goals of mathematical tasks

When depicting their lesson, Pamela and Sienna had opportunities to discuss and examine the goals of the tasks in their lesson plan. For example, the second and third tasks from their lesson plan were not clear regarding the goals and operations that students would be engaged in. However, when creating the lesson slides, they elaborated what they expected students would be able to achieve and what kinds of thinking process they anticipated students would have.

Examining mathematical representations on the board

The activity of creating board content in *Depict* provided a context for the participants to discuss mathematics. When drawing a double-entry table on the board, the pair had a different understanding of where to place the two variables as *x*- and *y*- values in the two columns. Their discussion revealed that their mathematical knowledge in teaching was limited and showed a need for additional resources for developing such knowledge. However, it seems to suggest that the creation and visualization of the board content provides a context for examining their understanding of mathematics and the ways in which they intended to present in their lesson.

Identifying resources for students

The pair of participants became aware of the need of resources for students to complete the tasks when depicting a lesson. Specifically, the activity of creating board work allowed the pair to attend to the sequential relationship between two adjacent tasks and to provide resources from a previous task for completing the current one. For example, in the third task of the lesson, the pair intended to ask a student to draw a graph on the board. When creating Slide #7, the pair specifically noted that the table presented earlier should be on the board as a resource for the current task.

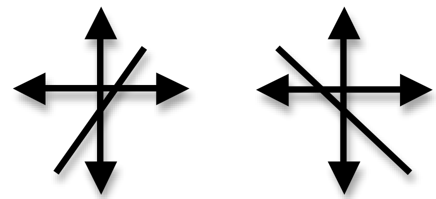
Case #3: Serena and Beth's work

Beth and Serena depicted three of the tasks they had planned and discussed the fourth. In this section, I only compare and discuss these tasks. When depicting the lesson, Serena and Beth decided to modify the task structure, that is, to integrate two of the tasks. As a result, two tasks were represented with eleven lesson slides, and they discussed the last task without composing lesson slides due to time constraints. These three tasks involved observing the differences of two graphs with different slopes, identifying slope from linear equation and finding slope from the change pattern of sets of points in a table.

Anticipating Task #1

In Beth and Serena's lesson plan, the first task is to have students identify the differences between positive and negative slopes of lines shown in graphs. Two resources are provided for students to accomplish the task. First, graphs of two lines with different slopes are shown to students. Second, students' prior knowledge about slope or linear function may help them better relate to how it is represented in graphs. The operations students were required to perform include applying their prior knowledge and observing that the two graphs go in different directions. After the introduction of positive and negative slopes, the pair intended to give a brief introduction of the day's topic regarding the definition and representations of slopes.

Show students 2 graphs



Ask students: (1) what is different about these 2 graphs? (expected student response: one goes one way and the other goes another way) (2) Why do they "go different ways"?

Tell students that different slopes are different. One slope is positive and one is negative.

Refer to prior knowledge: (When you have learned about slope and /or linear functions before)

We will focus on what slope means, how it's defined; how we find it and different ways it is represented.

Figure 43. The first task in Beth and Serena's lesson plan.

When composing the first slide, Serena selected a slide template with the virtual teacher writing on the board. Based on their lesson plan, Serena first drew two sets of coordinate axes side by side using the drawing tool. She then drew a line on the left coordinate system. The line was stretched from the lower left corner to upper right corner, indicating its positive slope. Then she drew another line on the right coordinate system. The line was stretched from the upper left corner to lower right corner, indicating its negative slope. None of these lines passed through the origin of the coordinate system.

After Serena drew the graphs, Beth suggested labeling the *x*- and *y*-axes. The labeling of axes had been missing in their lesson plan. Serena then labeled the axes on the two graphs and attached it to the board (see Figure 44).

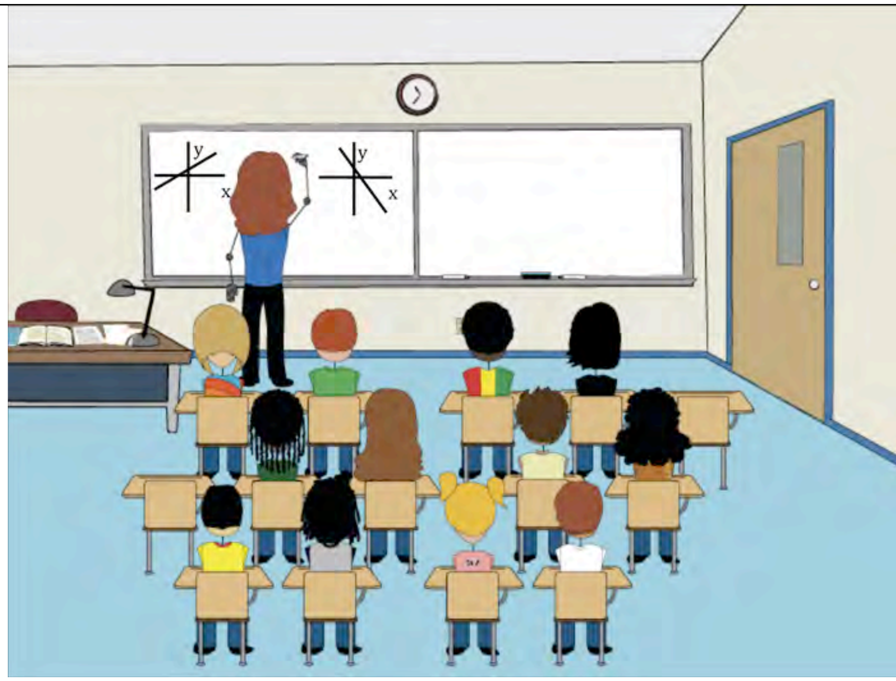


Figure 44. SB-S01: The virtual teacher is drawing two graphs on the board.

After the virtual teacher presented the graph on the board, the pair of participants planned to have her turn around facing students and ask the question about the differences between the two graphs. Serena selected a slide template with the virtual teacher standing at the center facing students. She then suggested posting the graphs drawn earlier on the left side of the board. Beth identified that if the graph was posted on the left side of the board, then the virtual teacher had to stand aside in order not to block what had been presented on the board. Hence Serena changed the slide template to the one with the teacher standing on the right side of the class. Then Beth typed in a speech bubble to have the virtual teacher ask students to compare the differences between the two graphs on the board (see Figure 45).

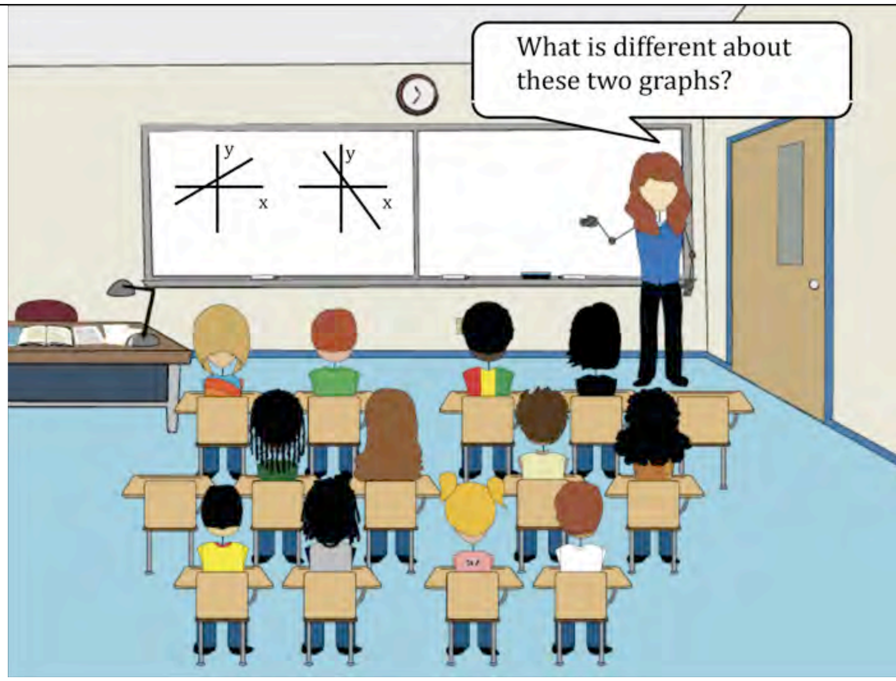


Figure 45. SB-S02: The virtual teacher is standing aside to not to block what is presented on the board.

Serena duplicated Slide#2 as Slide#3 because the pair intended to keep the board content the same in Slide#3. The pair planned to have a student respond to the teacher's question. They anticipated that a student, who they named Jamie, and who was sitting in the first row, would have an answer. Jamie was in the class that the pair was observing in their field placement. Beth first typed up Jamie's response: "One goes one way and the other goes the other way." This response was copied from their lesson plan. After typing the response up on the slide, the pair read through it and decided to revise it to "One graph goes one way and the other graph goes the other way."

Later, according to the lesson plan, the virtual teacher was supposed to ask a follow-up question about the reason of the differences between the two graphs. Beth copied from their lesson plan and typed in a speech bubble: "In response to student: Why do the graphs go different ways?" After viewing the question in the speech bubble, Beth suggested to have the virtual teacher ask: "Why do the graphs go different directions?"

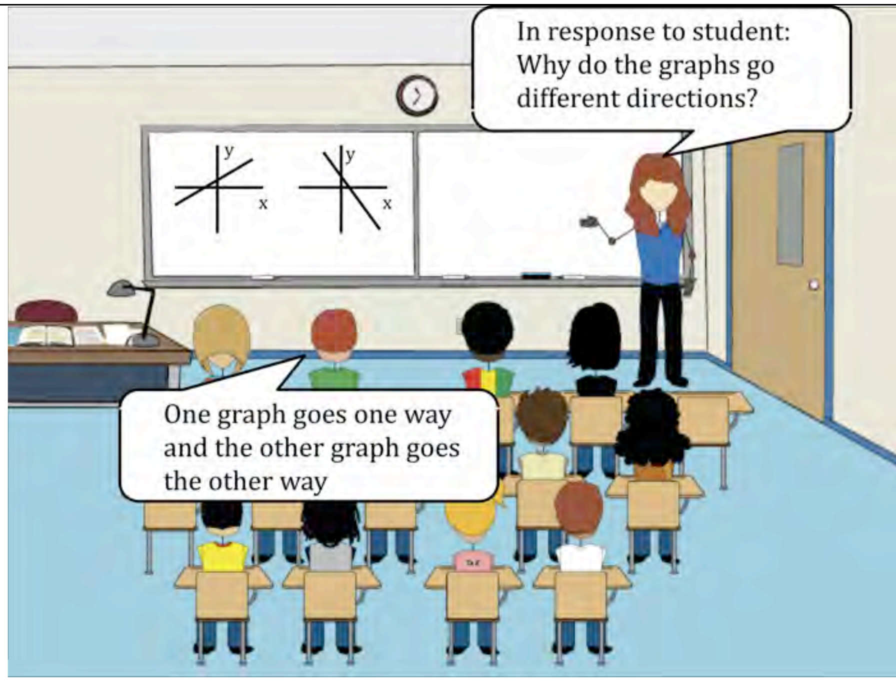


Figure 46. SB-S03: The student's response and the virtual teacher's follow-up question were modified from those written in the lesson plan.

Serena duplicated Slide#3 as Slide#4 to keep the same board content in the background. The pair read their lesson plan and discussed what would happen next. In the text, they had planned to have the teacher tell students that the slope of one graph is positive and the other is negative. Beth reflected that if a question was posed in the previous slide, then there should be responses from students or the virtual teacher would have to answer herself. However, when considering the typical teacher-student interactions in the class they observed in the field placement, they anticipated that the students would not respond and the teacher would have to explain herself.

143	Beth	Well okay so we asked why the directions are different. Someone is going to respond unless we answer our own question. (So do you want the same person to respond?)[15]
144	Serena	(Do you think the same person would respond?)
145	Beth	I think we assumed they wouldn't.
146	Serena	Yeah I don't think—I don't know if they would. Last Thursday they wouldn't have.
147	Beth	Yeah that's true.
148	Serena	But…
149	Beth	Um, I honestly—I don't think they would respond. So--
150	Serena	So I think we should just say—just give the answer to the question that she just asked.
151	Beth	Yeah we'll say like, we'll do the little thingy with the caption and it's like no student responded so then we responded.

Later, they also reflected that even though there was no response from students, the question posed earlier was to set up the need for the following instructional activities.

166	Beth	Plus I think we asked that question intentionally knowing they wouldn't know the answer so that--
167	Serena	It sets up the need for what's coming next.

[15] Parentheses indicate overlapping speech.

Hence, instead of composing the slide using the duplicated background with the graph on the board and teacher standing in front of the class, Serena inserted a new slide as Slide#4 with a blank background and typed in a caption box to note that no students responded the teacher's question (see Figure 47).

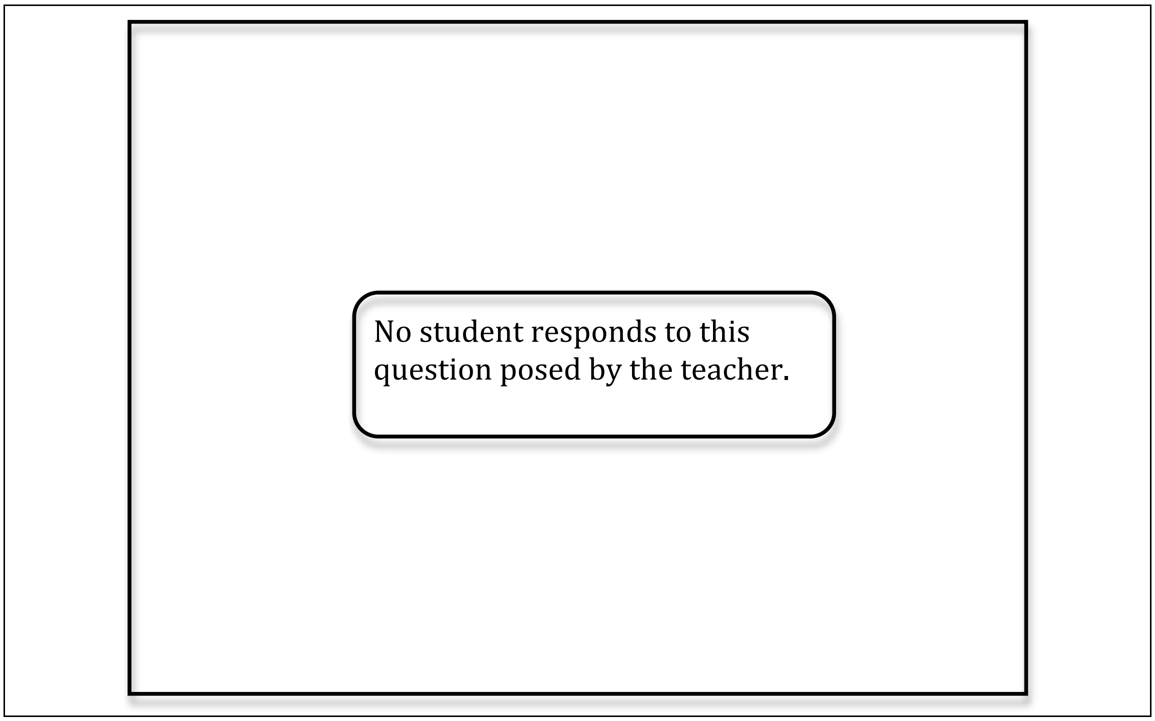


Figure 47. SB-S04: This slide was inserted to show the students' reaction at the moment.

In the following two slides, the virtual teacher explained that the two graphs have different slopes. When the participants were composing this slides, they commented that they would walk around the classroom and point to the graphs when explaining. The pair assigned pointing gestures on both slides as to show that the virtual teacher pointed to the graph when referring.

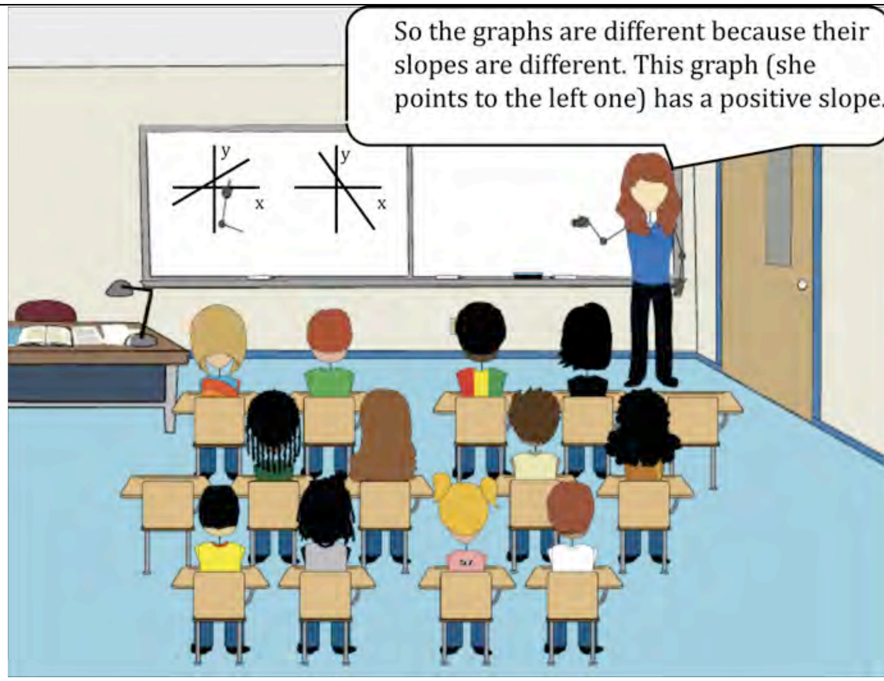


Figure 48. SB-S05: The virtual teacher points to the graph explaining it is a positive slope.

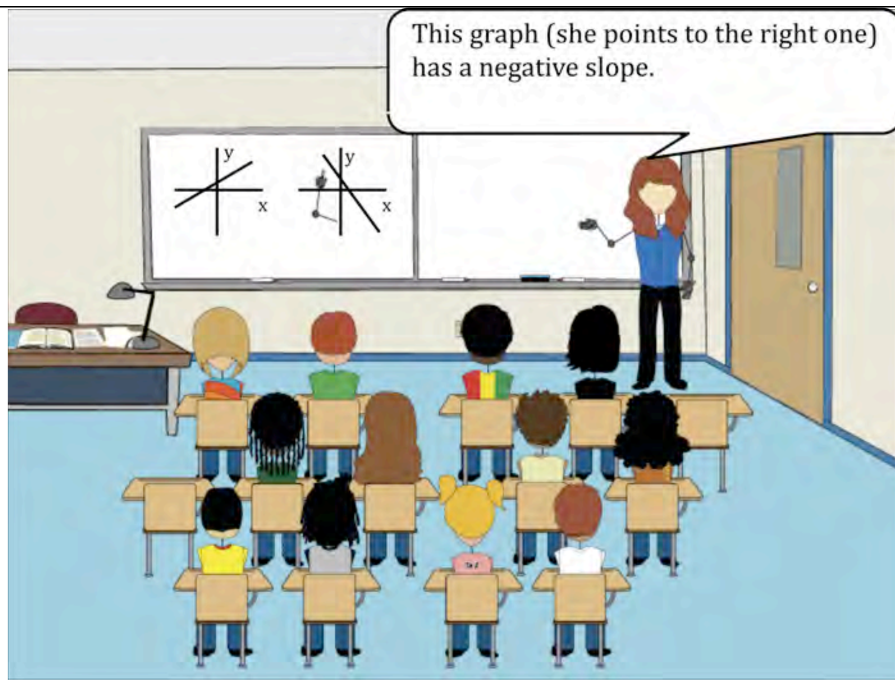


Figure 49. SB-S06: The virtual teacher points to the graph with a negative slope.

In each of the two slides above, a pointing gesture was assigned to illustrate that the virtual teacher points to the corresponding graph when explaining. It shows that the participants were able to ignore the disbelief of the representation itself and make use of the representation of lesson slides to illustrate their anticipation of the lesson.

Analytical commentary on Task #1

The creation of board content in *Depict* allowed the pair to visualize and examine the details they intended to present. When the pair planned their lesson in text-based format, they intended to present two graphs with a positive and a negative slope respectively. However, they sketched the graphs without labeling the axes. When depicting the lesson, they copied the two graphs from their lesson plan to the board in the drawing tool. After viewing what was drawn on the board, they realized that they needed to label the axes.

The work of viewing slides helped the participants to visualize and modify the board work and the virtual teacher's sequential moves in the classroom. For example, when beginning to compose Slide#2, they intended to have the virtual teacher face students and ask them questions. Thus the pair selected a slide template with the teacher standing on the left side of the board. When viewing the selected template, the participants realized that the board work presented earlier was on the left side. In order not to block what had been presented on the board, the virtual teacher should stand on the right side instead. Visualizing the classroom setting on lesson slides provided the participants a context to examine what had happened before and what should happen subsequently regarding the board work and the teacher's moves.

The activity of depicting a lesson enabled the participants to articulate what they, as the teacher, should say to students. It also helped them to anticipate student responses. When composing Slide#3, the pair intended to follow their lesson plan to determine the teacher's question and a student's response. However, they found that they would need to articulate the dialogues. Although it is not clear why the pair of teachers modified the dialogues, it is apparent that lesson depiction provided the opportunity for them to examine the dialogue they intended.

The activity of depicting a lesson helped the participants to anticipate interaction between the teacher and students. For example, viewing the slide template (duplicated from Slide#3 in which the virtual teacher posed a question) enabled the pair to realize that there should be students' responses after the question, or the teacher would have to answer herself. This interaction had not been attended to in the pair's lesson plan.

Further, when anticipating the interaction between the teacher and students, the pair referred to typical teacher-student interactions in the class they were observing in their field placement. They hypothesized that no students would respond. As a result, they added a blank slide describing that no student responds at the moment.

When depicting their lesson, the pair attended to specific behaviors they would enact. For example, in Slide#5 and Slide#6, they commented they would walk around and point to the graphs on the board specifically when explaining. The virtual teacher used gestures to point to the graphs. These specific moves demonstrate that the pair immersed themselves in the context of classroom explaining and interacting with students verbally and nonverbally. However, such anticipation of teacher's moves was absent in their lesson plan.

As can be seen on Slide #5 and #6, the virtual teacher was originally talking to the class using her right arm. However, a pointing gesture also appeared to indicate that the virtual teacher was pointing to the graph. The pair of participants made a note in the virtual teacher's speech bubble, explaining the pointing action. They were aware of the limitation of the representation and had written description to compensate. They seemed to neglect the realism of the representation of lesson slides; instead, they made use of this media to illustrate what they intended to happen.

Transitioning from Task #1 and Task #2

At the end of the first task of their lesson plan, Beth and Serena intended to give students a brief introduction to the day's topics. When depicting the lesson, the pair intended to follow what had been written in the text. They discussed whether their students would understand the virtual teacher's introduction involving multiple topics. They reflected that the students in the class they were observing in the field placement were used to hearing long introductions from their teacher.

205	Beth	Do you want to shorten that at all, I think it's kinda long. I don't think they'll focus on what slope means, how it's defined, how will you find it in different ways it's represented it, is that too long?

206	Serena	I think they are used to hearing things like that.
207	Beth	Yeah.
208	Serena	I think it's shorter than what they are used to hearing.
209	Beth	That's true.

When planning the lesson in text, the pair did not seem to take any student role into consideration. However, when depicting the lesson, the pair took the students from their field observation as a reference when anticipating the virtual teacher's instructional moves. They were engaged in anticipating a lesson that they thought they would be teaching.

Reviewing lesson slides

When finished the first task, the pair reviewed the lesson slides they had created that far. Beth and Serena played the role of teacher and students respectively to read through the dialogues that had been anticipated in their lesson slides. They did not make any changes while reviewing. This may owe to the fact that they did not encounter any difficulty in composing slides in the first place.

Anticipating Task #2

The second task described in Beth and Serena's lesson plan is not comprehensive. Based on what they wrote, it can be assumed that they intended to ask students to predict the changing pattern of two variables through a graph. They also intended to instruct students in using the slope formula to find out the equation of the graph[16]. The resource that they counted on students to have was the equation of a linear function (*y=mx+b*) that they assumed students had learned before. However, it was not stated what operations students would have to perform to achieve the task.

> Seen slope before in linear eqn y=mx+b, where slope in that equation is m and m is equal to/can be found by $\frac{y_2 - y_1}{x_2 - x_1}$. This describes a linear relationship between points.
>
> Example: 1 step / 1 desk; if I walk 4 steps then which desk will I be at? Refer to predicting a pattern with the points on a graph. Relate this to y=x.

Figure 50. The second task in Beth and Serena's lesson plan.

When discussing the lesson slides, the pair made it explicit how students' prior knowledge of linear function relates to slope (Turn 246-247). They intended to present the formula, $m=\frac{y_2 - y_1}{x_2 - x_1}$, on the board and explain to students that one can find out the slope using the formula.

246	Serena	On the board? And do we want this on the board, or no?
247	Beth	Yeah, so we could say like, so remember when you learned before about another way to represent is with the linear equation, y = mx + b, and then we'll say um, so the slope in that equation, you find it using this. [Serena: Okay.]

The pair employed what they assumed was students' prior knowledge about linear functions as a resource to introduce students how to find the slope from the

[16] The pair of prospective teachers seemed to assume students would already know the more complicated formula for slope, while they in fact still had to learn the concept of slope.

equation. However, when discussing about how to represent the equation of the slope, they realized that the slope formula, *m*= $\frac{y_2 - y_1}{x_2 - x_1}$ that was written on their lesson plan and represented by letters, could be too confusing to students. They considered that using numbers obtained from an example to illustrate the concept of slope might be easier for students to understand.

264	Beth	So I was thinking about this, do we want to have letters like this? Or do we want to have numbers?
265	Serena	Numbers right?
266	Beth	I think so, I think it'll be less confusing. Especially the way we wrote the letters right there, like y_2 and y_1.
267	Serena	Yeah that's--
268	Beth	I think that's too confusing.

The example proposed in their lesson plan was that if one goes one step, then he will be at the first desk. This example is with the linear function of $y=x$ where it has slope of one. The pair intended to follow this example and illustrate it graphically on the lesson slide. Serena drew a coordinate plane in *Inscribe*. She drew two lines across each other at the origin as *x*- and *y*-axes. Then she drew an arbitrary line stretching from the lower left corner up to the upper right corner, and asked Beth if they needed to make the line cross the origin. They agreed to do so without further discussion.

Then Serena arbitrarily drew two hash marks as units on each axis. The two hash marks on each axis were sparsely marked. They discussed if they would need to mark all the units on each axis. Serena reflected that the cooperating teacher in the field placement once told her that a teacher has to make unit marks on the two coordinate axes; otherwise, students would think they did not exist. Hence, Serena went on drawing seven and six hash marks on the *x*- and *y*- axis respectively. These marks were for the most part equally spaced.

271	Serena	Okay. And then we have this point here, and this one here, and here. Should we tick all the lines? I think we should do all of them.
272	Beth	Oh, yeah I see what you mean.
273	Serena	'Cause that's, I asked her about that in the drill and she's like they will think they don't exist, what?
274	Beth	Yeah I was wondering about that too.

After marking the axes, Serena and Beth picked two points on the line as the example, for the purpose of finding the slope of the line. They picked point (2,2) and (5,5) and Serena typed the coordinates of both points on the graph. However, after viewing the coordinates of the two points, Serena commented that the two chosen points were "too special of a case" (Turn 294). Beth agreed that the slope of the line would be one and "it might generalize to everything" that students "might think all the slopes are the same." Serena argued that as the first example of finding the slope students would encounter, this kind of example might be easier for them. But Beth countered that the choice of numbers in this example would be confusing because the *x*- and *y*- values are the same and the *x*- and *y*- values of change are the same too.

294	Serena	So we have two two [coordinate point] and then we have five five [coordinate point] is that too special of a case?
295	Beth	Oh 'cause the slope's gonna be one you mean? Um, yeah I guess we don't want to have a special case, 'cause then it might generalize it to everything.
296	Serena	Yeah but it might make it easier for the first one they do.
297	Interviewer	So if you present this special case, what the student would think about?
298	Beth	Well then they might think all the slopes are the same.
299	Interviewer	Yeah.
300	Beth	Plus, like if you used these same numbers it's not clear which one's the Y and which one's the X. Or y'know you change Y to change X (they're both gonna be five minus two.)
301	Serena	(They're both gonna be three.)
302	Beth	Yeah it's gonna be tricky.

As a result, the pair decided to revise the example. Serena first moved the line around and made it away from the origin. But Beth reminded her that the slope of the line would still be the same. Hence, Serena deleted the line and the two points.

She first extended the negative *y*-axis and drew three hash marks on it. She then drew a line passing below the origin, and asked if it was desirable to pick a point on the intercept on the negative *y*-axis. They then arbitrarily chose two points, (0, -2) and (4,3). However, when viewing the line with the two points, Beth commented that the slope of this line was still one[17] and suggested to pick two points first then draw the line.

316	Beth	You still made the slope one.
317	Serena	I did?!
318	Beth	Yeah. Yah two over two.
319	Serena	This, this is five.
320	Beth	Yeah, put the points first like where you want it and then draw the line.

In the above activity, Beth and Serena found that the example they chose initially was a special case that might confuse students. However, they seemed to choose another example arbitrarily by picking up two points from a drawn line. They did not think deeply about the choice of numbers for the example in their lesson.

Finally, Serena deleted everything in the drawing tool. She first picked a point at (4,5) and then connected it with point (0, -2) with a line. She labeled the coordinates of these two points and attached the whole graph to the right side of the

17 The slope of the line which passes through (0,-2) and (4,3) is, however, 5/4, not 1.

board. Later, she attached the previous graphs (two graphs with negative and positive slopes respectively) to the left side of the board. Beth commented that presenting the previous graphs and current graph on the board side by side helps students to compare the differences and similarities of the graphs: “It’s like a progression on the board, they have something to look back to and compare to, like when we find this slope then they will be able to compare it to, ‘oh yeah, that’s why that one was positive’.”

In the same slide (see Figure 51), the virtual teacher explained what was written on the board. She first reminded students of the equation formula that they had learned before and explained that students would need to find the slope of the graph on the board.

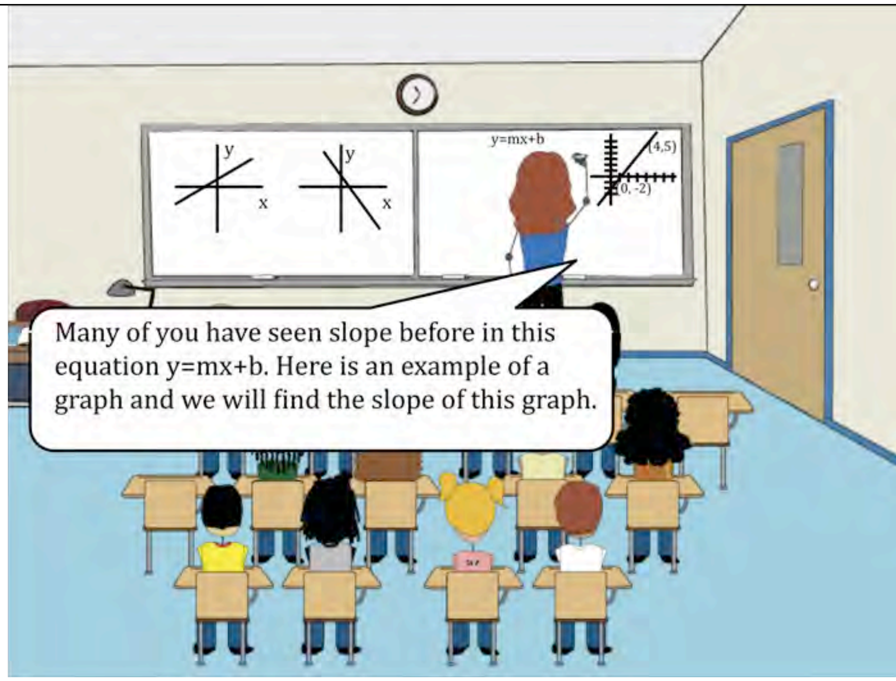


Figure 51. SB-S07[18]: The virtual teacher reminds students of the formula and explains that students have to find out the slope of the graph.

Integrating Task #2 with a follow-up task

After composing Slide#7 in which the virtual teacher provided the formula and asked students to find the slope of a given graph, Beth and Serena viewed the slide, discussed and clarified the task. Beth first questioned whether there was a need to provide the linear equation formula on the board (as shown in Slide#7). She suggested that it would be better to provide the equation of the given graph to students. In doing so, students were left to identify the slope from the given equation. Serena clarified that the task was to have students find the slope and identify "m" in the equation as the slope. Hence, she was inclined to have students calculate the slope themselves.

[18] Later, when Serena and Beth reviewed this slide, they changed some wordings as the virtual teacher was saying: "Many of you have seen slope before in ~~this~~ the equation y=mx+b. Here is an example of a graph ~~and~~, we will find the slope of this graph."

Then Beth reflected on the following task proposed in their lesson plan and compared those tasks to the one presented in Slide#7. She found the two consecutive tasks were related and could be integrated together. The pair decided to proceed with the later task, which was to ask students to find the slope given two points on a line.

390	Beth	Okay so, but like I'm just saying like if we write this equation and then we write a graph and then draw an example from the graph it's like well why did we even throw that equation up there?
391	Serena	I think to find—like to show it's relationship in the equation, what is M, what is slope, where can I use it?
392	Beth	So if we're gonna do it--
393	Serena	'Cause then we--
394	Beth	I don't think these two should be disconnected anymore.
395	Serena	You think it should be the same?
396	Beth	Like 'cause we're doing this right now, like we changed it from this.
397	Serena	So then lets go right into this.
398	Beth	Yeah, lets just cut that, it doesn't make any sense.
399	Serena	Okay sounds good.
400	Beth	Okay.

Serena duplicated Slide #7 as Slide#8 as a way to keep all the board content and the virtual teacher's standing position the same. The pair discussed whether they needed to write up the calculation of the slope on the board or they would ask students to do the calculation on their own. Then, they discussed whether students would be able to do it if they were asked to do the task. Serena first commented that students would not know how to calculate the slope. Beth wondered what students would respond given that they had learned the equation before. And Serena anticipated that students would forget what they had learned. Beth conjectured that students would possibly remember "rise over run" as an answer.

Then they decided not to have the same slide background as Slide #7 in which the virtual teacher was writing on the board. Instead, they intended to have the virtual teacher turn around facing students and ask students to find the slope.

410	Beth	Do you think they know the answer?
411	Serena	I don't think so.
412	Beth	Even if they don't, I wonder what they would say. Like, well if they've already learned it before. But--
413	Serena	I don't think they remember it exactly.
414	Beth	Well I would guess one of their answers would be like slope is rise over run.
415	Serena	Yeah. Okay.
416	Beth	So--

417	Serena	So then we shouldn't have this slide.
418	Beth	(Should have)
419	Serena	(We should have) a new slide that has her turning to the classroom?
420	Beth	And asking them to find the slope?

After changing the slide template for Slide#8, the pair discussed how the virtual teacher would pose the question about asking students to find the slope. Before typing up the virtual teacher's question, Beth also proposed how students would respond to the question and how the teacher would follow up with the students' answers. Thus, the pair not only considered the teacher's initial move at the moment, but also they attended to students' possible responses and the sequences of the interactive moves between the teacher and students in their lesson.

429	Serena	She's asking how do you, how would you find slope? Or how do you think we can find the slope?
430	Beth	Hmm. [hums]
431	Serena	What can we use to find the slope, this line?
432	Beth	Okay so if you say that then someone would say um, like the two points. [looks at Serena]
433	Serena	[nods]

434	Beth	And then we'd say okay now how do you use the two points, so it would be like kinda back and forth.
435	Serena	Yeah.

When considering the students' response, they anticipated Mike, a student in their placement class, would answer the question.

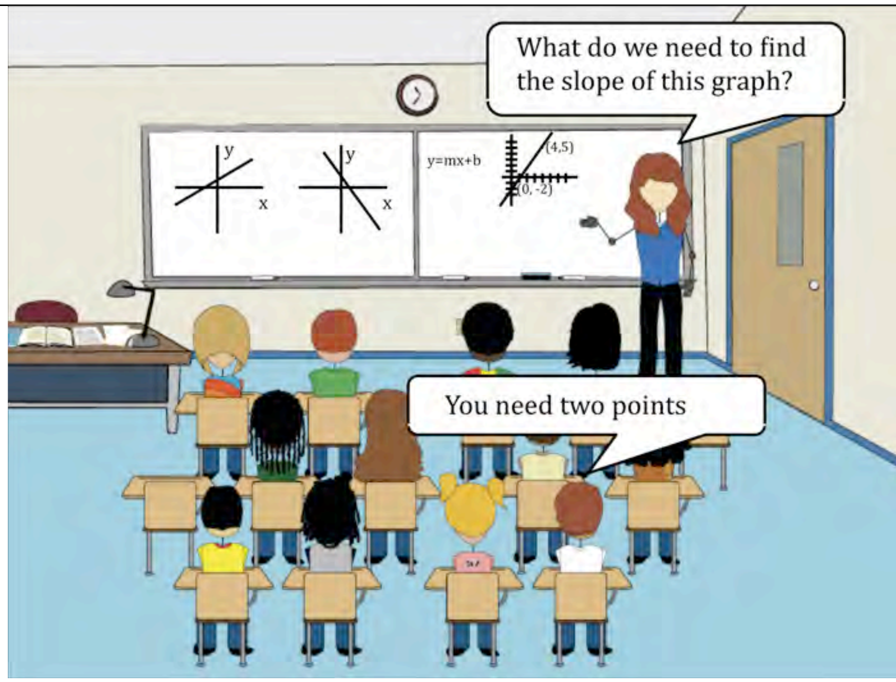


Figure 52. SB-S08: A student named Mike answers the question.

The pair continued composing the next slide in which the virtual teacher kept prompting students how to use two points to find the slope. Serena duplicated Slide#8 as Slide #9, and Beth typed up the virtual teacher's question.

Serena asked whether the virtual teacher would directly ask Mike to answer the question. Beth explained that the virtual teacher would like Mike to elaborate his answer and hence Mike should answer the follow-up question. The pair discussed what his answer would be and how he usually behaved in class.

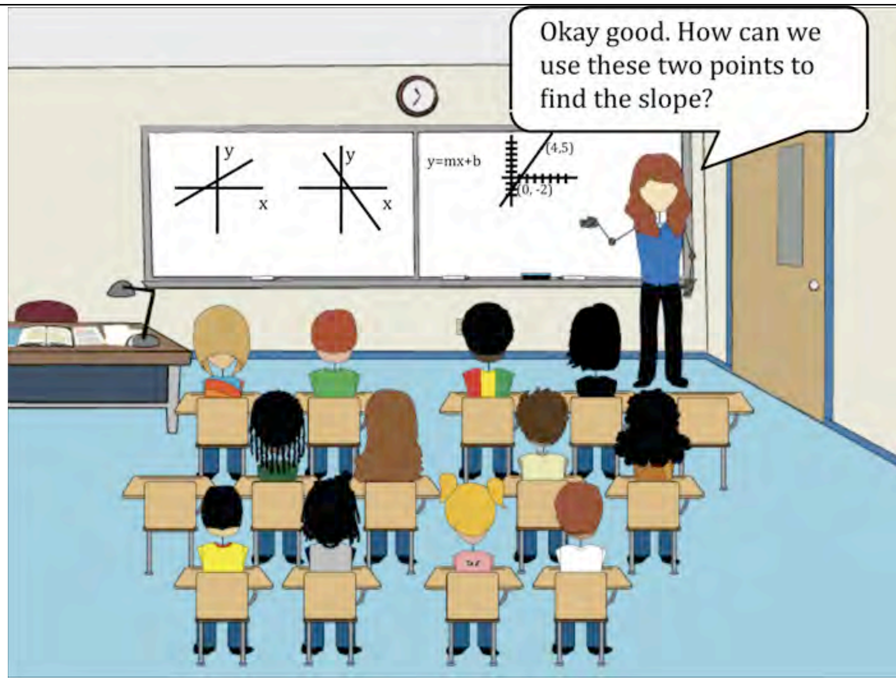


Figure 53. SB-S09: The virtual teacher asks a follow-up question.

As the pair discussed more about Mike's possible responses, they realized the need to have a classroom scene with students in which they could visualize Mike's expression and more of other students' verbal and nonverbal responses.

453	Serena	... Him again?
454	Beth	Umm...yeah because we want him to elaborate on his answer.
455	Serena	Okay. So then maybe he'd be like "I don't know, rise over run?" I feel like--
456	Beth	Yeah, that he might be a bit unsure?

457	Serena	Yeah.
458	Beth	So…
459	Serena	Sometimes he gets apathetic in his answers too.
460	Beth	Yeah. Um…
461	Serena	I don't know, if he can't say I don't know, so. [laughs]
462	Beth	Yeah. Maybe like um, I think you would—should we like have it show the class?
463	Serena	And their expressions?
464	Beth	Yeah.
465	Serena	Okay, so lets just get rid of this.
466	Beth	Yeah.

In the slide template with a class of students, Slide#10, several students were involved in the lesson. Besides Mike who answered the question with an uncertain expression, other four students were seen bored or not excited. These students were identified with individuals from the class the pair was observing in the field placement.

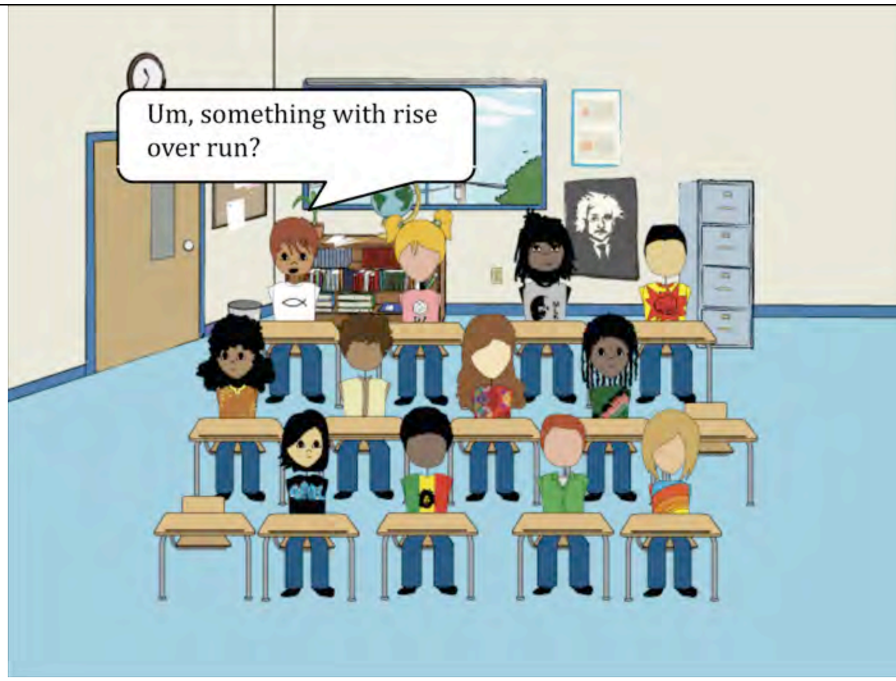


Figure 54. SB-S10: Mike answers the question while other students are bored.

Serena duplicated Slide#9 as Slide#11 in which the slide has the board content as the background. The pair discussed what to present on the board to show the calculation of the slope of the graph. They considered writing what the student had said about "rise over run." They also considered writing the description of the value changes in *y*- and *x*-coordinates. They then concluded that writing both notions on the board is "better for them" (Turn 537) because it helps to connect what the student did, the mathematical concept and the calculation of the example ("because then it takes what they did to 'math' to the number", Turn 538). Hence the virtual teacher presented the following illustration on the board:

$$\text{Slope} = \frac{\text{Rise}}{\text{Run}} = \frac{\text{change in y – coordinates}}{\text{change in x – coordinates}}$$

$$= \frac{0-4}{-2-5} = \frac{-4}{-7} = \frac{4}{7}$$

Figure 55. The virtual teacher presented the equation on the board.

531	Beth	So do—are you going to write like slope equals—are you gonna write, are you going to write out in words like um, change in Y and then change in X.
532	Serena	Okay. So--
533	Beth	Or do you want to write what he said, rise over run?
534	Serena	Lets write rise over run (equals) [Beth: (I think that--)] change in Y over change in X equals [inaudible].
535	Beth	So write out two things of words you mean?
536	Serena	Yeah.
537	Beth	Okay, that's fine, I think that's better for them, (honestly).
538	Serena	(Yeah because) then it takes what they did to "math" to the number.
539	Beth	Yeah, I like that.

As can be seen in Slide#11, the virtual teacher wrote down different algebraic representations of slope connected by equal signs, including "rise over run", the "M" formula and the calculation in numbers from the example. In addition, the virtual teacher explained this representation.

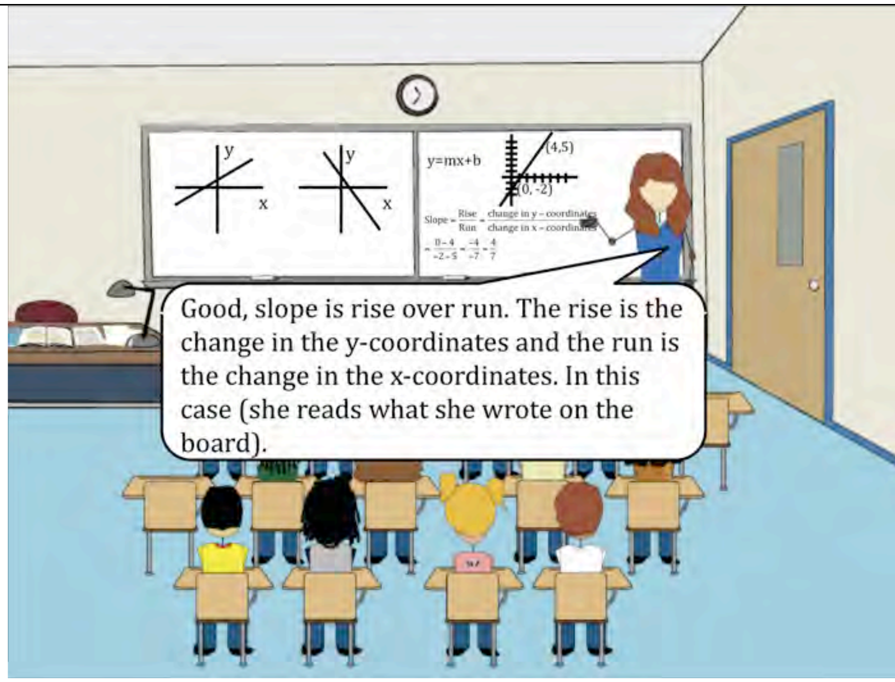


Figure 56. SB-S11: The virtual teacher wrote the calculation of slope on the board to connect what the student just said and to the mathematical concept of slope.

Analytical commentary on Task #2

The activity of depicting a lesson gave the participants an opportunity to examine whether the representations of the concepts are comprehensible. In Beth and Serena's lesson plan, they intended to introduce the formula for slope of a linear function that students had supposedly learned before. However, when depicting the lesson, they thought the formula might be confusing being represented by letters. As a result, they modified the plan and intended to use a word example to calculate slope.

The work of developing the representations on the board in *Depict* allowed the participants to examine their own understanding of the representations and anticipate students' understanding of them. For example, when the pair was drawing a coordinate plane and marking the units, they first wondered whether there was a need to mark all the units. Then they reflected from their field experience that the cooperating teacher advised them that marking the units helps students realize that all the units exist.

It was challenging for Beth and Serena to choose appropriate numbers in an example to illustrate the concept of slope. Based on their lesson plan, they intended to find an example with the slope of one. However, when representing the example on the coordinate plane, they found that the example might be a special case that might mislead students. In that example, the x- and y-values are identical and the x- and y- values of changes are the same as well. The choices of numbers would get students confused. It seemed helpful to have the participants visualize what they would present to students. In doing so, the pair would have the opportunity to examine the mathematical appropriateness of the examples deployed in their lesson and anticipate the kinds of operations involved in that example.

When depicting the lesson, the participants had to present and arrange board work. This activity helped them identify and provide necessary resources to facilitate students' learning. When presenting the example graph on the board, the pair noticed the need to keep the graphs presented earlier on the other side of the board (see Figure 51). They hypothesized that presenting two sets of graphs side by side would help students to review what had been discussed before and to compare the two.

The activity of depicting a lesson allowed the participants to evaluate the planned tasks and the connections among them. For example, when the pair was viewing a slide that they had just created (Slide#7), they realized that the two consecutive tasks in their text-based plan could be integrated. This shows that the pair first had considered that the tasks planned in the text as separate. However, the activity of lesson depiction enabled them to see tasks as related and connected.

The activity of depicting a lesson allowed the participants to consider the sequential interactive moves between the teacher and students. Particularly, the pair thought about how the teacher would pose questions, whether students would be able to answer them, what students could be capable of responding, and how the teacher could pose a follow-up question. For example, after Slide#7 in which the virtual teacher proposed to find the slope of the graph on the board, the pair discussed students' thinking. They wondered whether students would be able to find the slope. Based on their understanding of the students they had observed in the field placement, they hypothesized that their students would not know the answer. However, they further pondered the kinds of responses the students would give. In addition, they anticipated how the teacher could prompt further thinking.

When depicting the lesson, the pair consistently referenced the typical teacher-student interactions in the class they were observing in the field placement. They individualized students and hypothesized how students in that class would react verbally and nonverbally. For example, in Slide#8 in which the virtual teacher asked how to find the slope of the given graph, a student identified as Mike responded to the question. Later, after the virtual teacher prompted a follow-up question, Mike responded again in Slide#10. He was anticipated as “a bit unsure” when answering and “sometimes he gets apathetic in his answers too. (Turn 456, 459)” In the same slide in which Mike was giving his answer, other few students were nonverbally involved: they were given “bored” facial expressions.

When depicting a lesson, the participants anticipated the interactive moves between the teacher and students and specified the reasons for those moves. For example, after Mike answered the teacher’s question of how to find a slope, the pair made the virtual teacher probe for further answers (see Slide#8 and Slide#9). The pair intended to have Mike respond again because “we want him to elaborate on his answer.”

The work of writing specifically what to present on the board allowed the participants to consider which mathematical representations might help students understand better. For example, when thinking about what to present on the board to show the calculation of the slope of the given graph in Slide#11, the pair intended to integrate different mathematical representations and enable students to better understand the relationship among different representations. The pair thus had the virtual teacher write several algebraic representations of slope on the board, connected by equal signs. They considered students would better make connections among different representations of the same notion.

Discussing Task#3

The pair had implemented two tasks with eleven lesson slides. They integrated the second task with a follow-up task from their lesson plan. Due to time constraints, the pair discussed the following task but could not represent it with lesson slides.

In this task, the pair intended to use the table format to help students relate to the concept of slope. They intended to show a table with four sets of points and help students identify the patterns of change between quantities in the two columns. The task was not thoroughly planned, because the pair did not specify the coordinate points and how they would explain to relate the observation from the table to the concept of slope. Regarding this task, they wrote:

EX #2 (from table)
Show 4 points & make a table

Figure all pattern of numbers on each side of table separately and connect to slope (from change in pattern & predicting numbers)--check 2 sets of points

Figure 57. The task Serena and Beth discussed but did not implement in lesson slides.

When they read the task in the lesson plan, they commented that they would use the points from the graph from the previous task and put those points into a table, so it "is using the same example (to) connect it to the different representations." It shows that they identified the connectedness among the tasks in their lesson and did not treat the tasks as separate as they had done when planning in text.

Analytical commentary on Beth and Serena's lesson depiction

When using Depict, Beth and Serena attended to details that they had not considered in their written lesson plan. I discuss in the following sections.

Attending to teacher behavior

The work of viewing slides provides an opportunity for the participants to attend to teacher's behavior in the classroom setting. For example, when selecting a template for their second slide, they became aware of the board content on the one side. So they made the virtual teacher stand on the other side of the board.

In addition, the pair commented that they would walk around to point to the graphs on the board when explaining.

Articulating teacher verbal directions

The work of creating dialogues in *Depict* allowed the pair of participants to articulate what they, as the teacher, should say to students. They found that their planning in text, regarding the teacher's question and a student' response, had not been clear enough to represent the teacher-student verbal exchange.

Attending to representations of concepts

The work of depicting a lesson encouraged the pair to examine the comprehensibility of the representations of the concepts. For example, in their lesson plan, they intended to introduce the formula of slope represented by letters. However, when depicting the lesson, they reflected this kind of representation might be confusing. Consequently, they decided to employ an example to illustrate the idea of slope.

Projecting field experiences to lesson slides

When anticipating teacher-student interactions, the pair referred to their observations from field placement. They observed that typically, students did not show interest in learning. Hence, they hypothesized that no students would respond at the moment.

Another example also shows that the pair anticipated students' reactions based on their observation from the field placement. When the pair planned a transition between two adjacent tasks, they intended to give an introduction to the day's topics. They discussed whether their students would understand the introduction involving multiple topics. They then reflected that their students from the field placement were used to hearing the long description of topics. Consequently, they created a speech bubble involving the long introduction of the topics.

Attending to board content

The use of *Inscribe* to create board content allowed the pair to visualize and examine their presentations of the mathematical work. They first presented two graphs, copied from their lesson plan, on the board and intended to ask questions about the graphs. However, after viewing the graphs on the board, they realized that the axes in the graphs had not been labeled. They did not attend to this omission until they viewed it on the board.

Examining choices of examples

The activity of presenting board content afforded the pair opportunities to examine the mathematical appropriateness of examples. From their lesson plan, the pair originally intended to find an example with slope of one to illustrate the concept of slope. However, when presenting the example in *Inscribe*, they realized that the choice of the example was too general that would confuse students.

Overall, the activity of creating board content in *Depict* seems to allow Beth and Serena to examine issues in instruction that they had not attended before. For example, they became aware of their choices of examples in their lesson and the representations of concepts on the board. They also specified teacher's behavior and verbal directions in the lesson. In addition, they identified the class with their field placement class and projected students' typical reactions to their lesson depiction.

Case #4: Samantha and Millie's work

Samantha and Millie composed twenty-three lesson slides to implement four tasks from their lesson plan. They intended to have students graph coordinate points and have them observe the changing patterns in a table. Then they planned to employ graphs to illustrate the concept of "rise over run."

Anticipating Task#1

The first task in Samantha and Millie's lesson plan was to have students graph points on graph paper and have them observe the collinearity of the points. The resources were the graph paper with four points that teacher would give to students; however, it was not specified which four coordinate points would be given to students. The operation was that students would have to connect the given four points with a line on their graph paper.

Teacher gives students graph paper and ~4 (linear) points to plot. Then they connect the points in a line. The teacher points out that this is a straight line, so this is one way of seeing that we have a linear function.

Figure 58. The first task in Millie and Samantha's lesson plan.

When depicting the lesson, Samantha chose a slide template with the virtual teacher standing at the center facing students as Slide#1. She copied from what had been written in the plan to a caption box on the slide to describe the teaching event: "The teacher gives each kid a piece of graph paper and four (linear) points to plot." The virtual teacher then talked to the students that the class was going to have an exercise, which was to graph the points on the given coordinate axes.

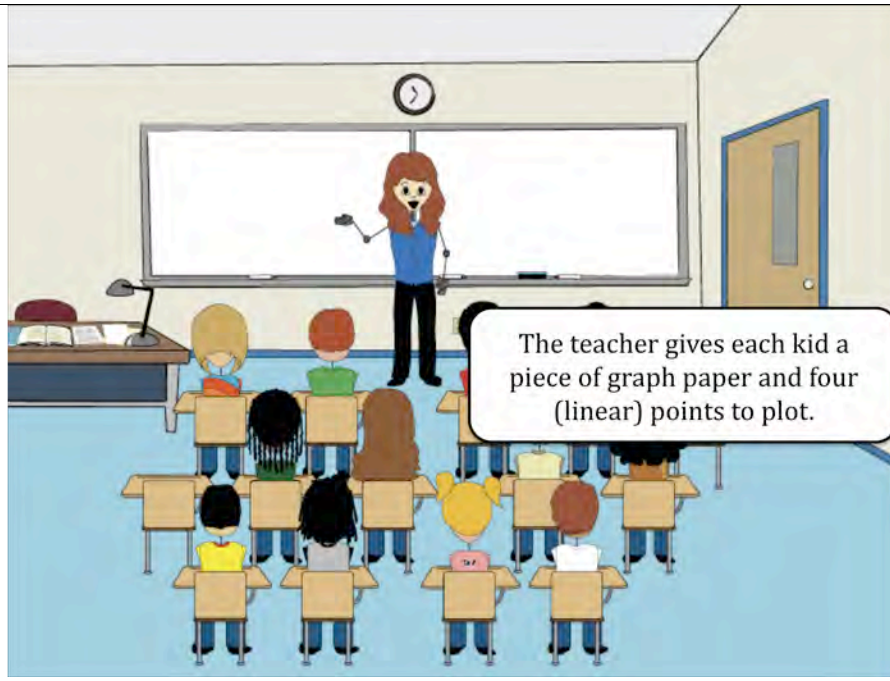


Figure 59. MS-S01-v1: The teaching event is described as what had been written in the lesson plan.

When creating the virtual teacher's verbal instruction to the class, Samantha realized that the graph paper given to students should include the coordinate axes for them to graph the points. So Samantha revised the description of the teaching event in the caption box that the virtual teacher gave each student "a piece of graph paper with axes and four (linear) points to plot." The given resources for students to graph points then include both four coordinate points and the graph paper with axes. The later resource was not anticipated in the lesson plan.

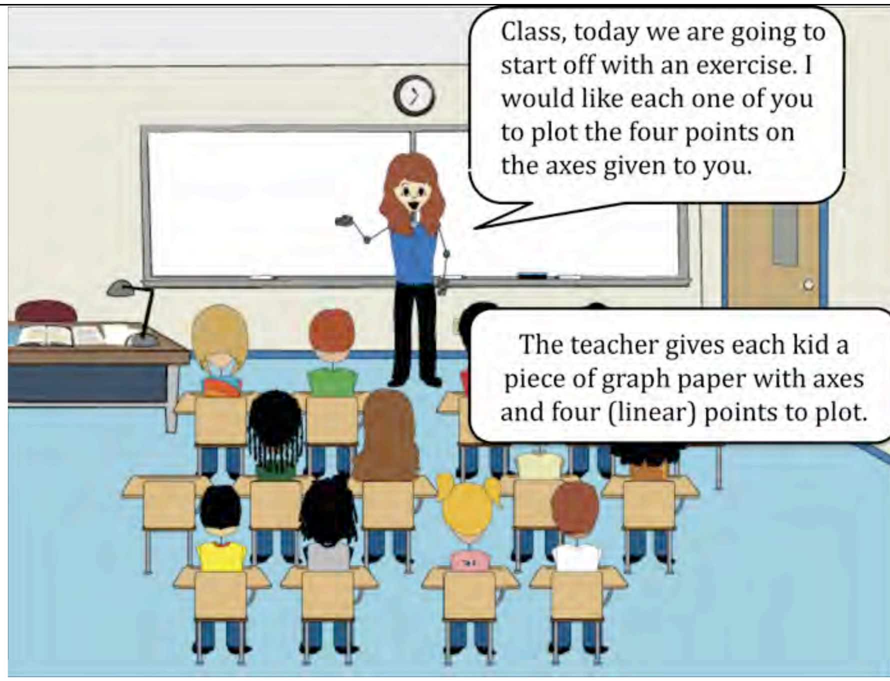


Figure 60. MS-S01-final: The virtual teacher provides graph paper with axes as a resource for students to plot the points.

To remind the students of plotting points, the virtual teacher provided an example on the board. She drew a coordinate plane and marked a point at (2,3) on the board. This example might help students to retrieve their prior knowledge of graphing. This example can be seen as another resource that helps students in the graphing task, but had not been identified when the pair initially planned the lesson.

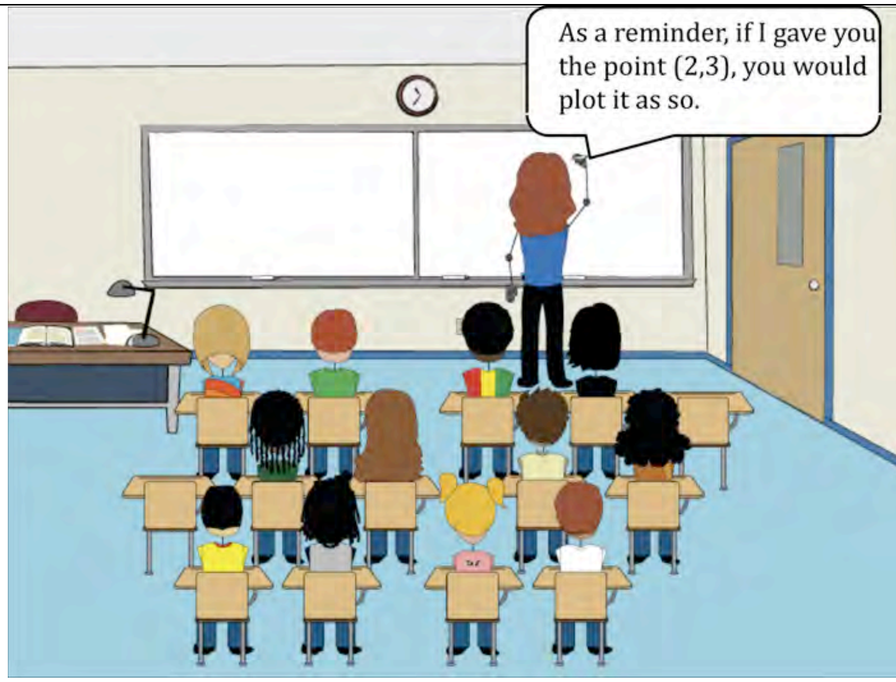


Figure 61. MS-S02: The virtual teacher reminds students of how to plot a point.

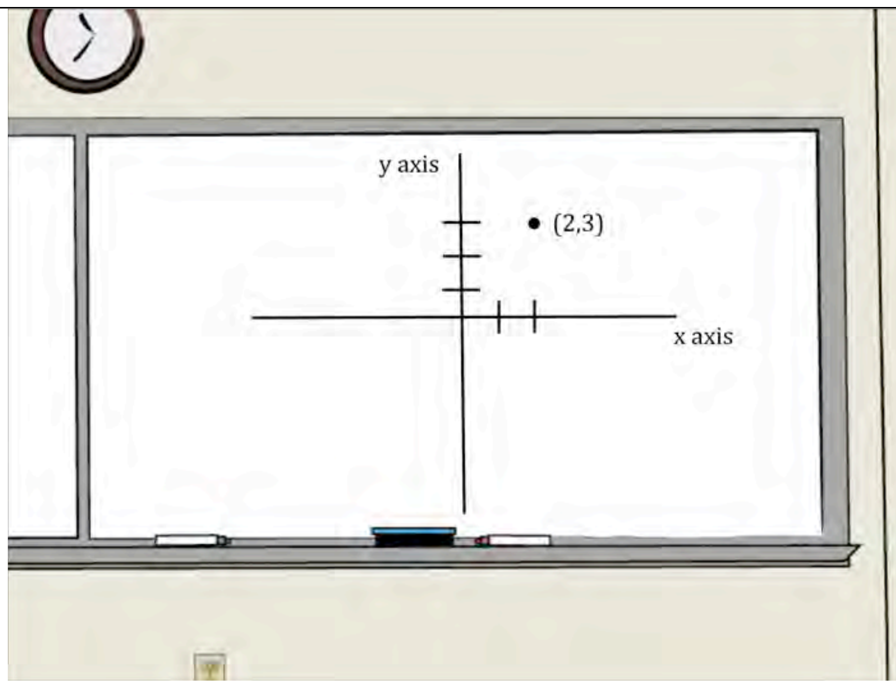


Figure 62. MS-S03: The virtual teacher draws a coordinate plane with a point as an example to show how to plot points.

The following slide, Slide #4, illustrates students' participations. Some student characters were assigned with writing arms to show that they were working on the task. A caption box says "After a couple minutes of working" indicating that it required time for students' work on the task. Then a student, who had a male-neutral speaking expression, raised his hand to claim that he had finished the work and asked what to do next. One other student showed her confusion and frustration on her face.

In their lesson plan, Samantha and Millie had not anticipated any students' involvement in the task or their reactions to the task. However, when depicting the lesson, in response to the teacher's assigned task, to plot points on the graph paper, the pair anticipated that the students would be working on the task and they needed time to do it. Besides, the pair anticipated students' verbal and nonverbal reactions during and after working on the task. For example, one student was confused. Another student was raising his hand and speaking when finishing his task.

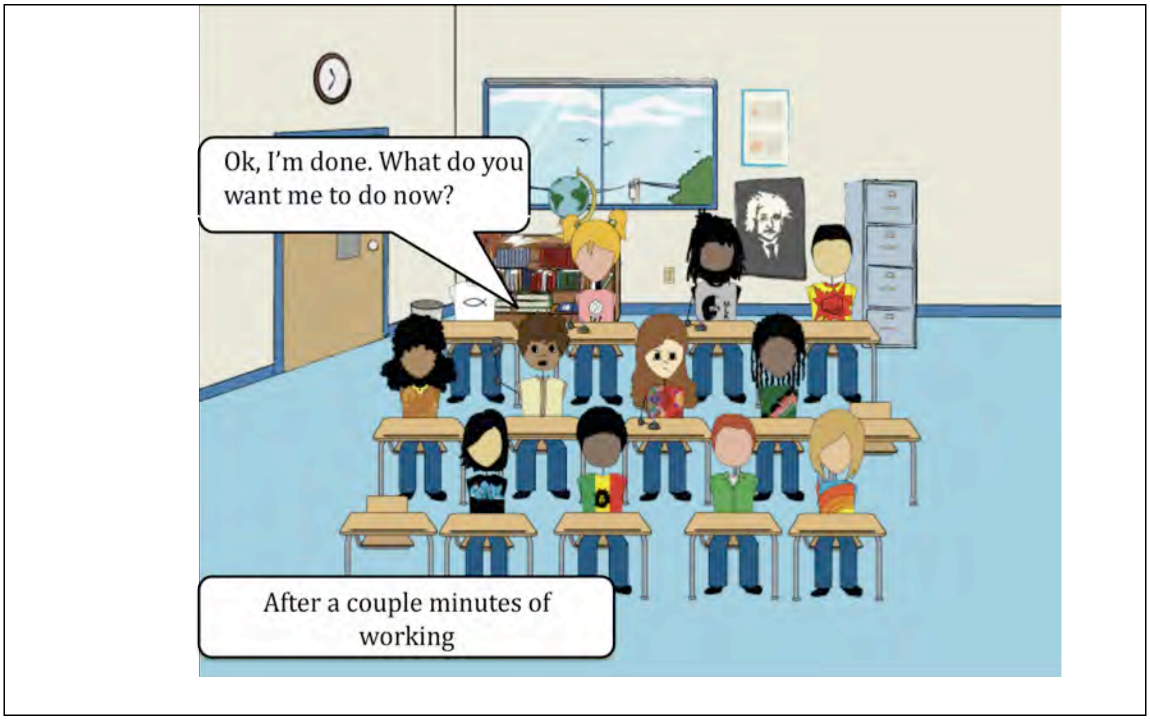


Figure 63. MS-S04: Multiple students are involved in the task.

After the class worked on the task, the virtual teacher followed up with a question to ask students to observe the points they had graphed (see Slide#5). In the following slide, Slide#6, which shows a view of the class, multiple students reacted in different ways. First, a student raised her hand and shared her observation. Then another student agreed with her classmate's answer with excitement. However, one other student who was sitting in the third row showed to be bored.

This sequence of interactive moves between the teacher and students had not been planned in text. In their lesson plan, they had only written "The teacher points out that this is a straight line." However, in their lesson depiction, the pair had the virtual teacher ask students for their observation from what they had worked on. And then they anticipated how students would react verbally or nonverbally.

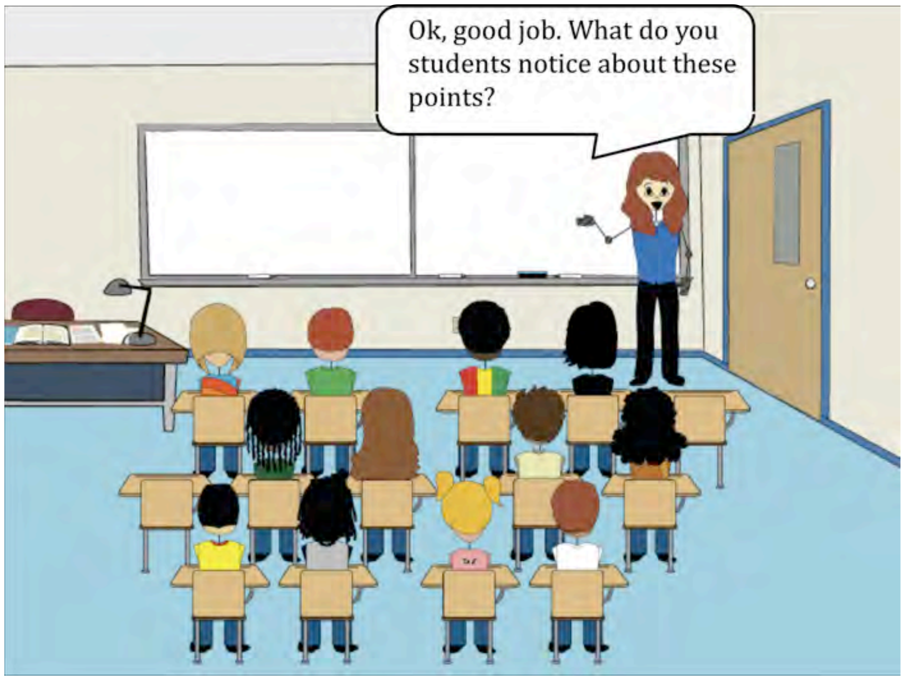


Figure 64. MS-S05: The virtual teacher asks a follow-up question.

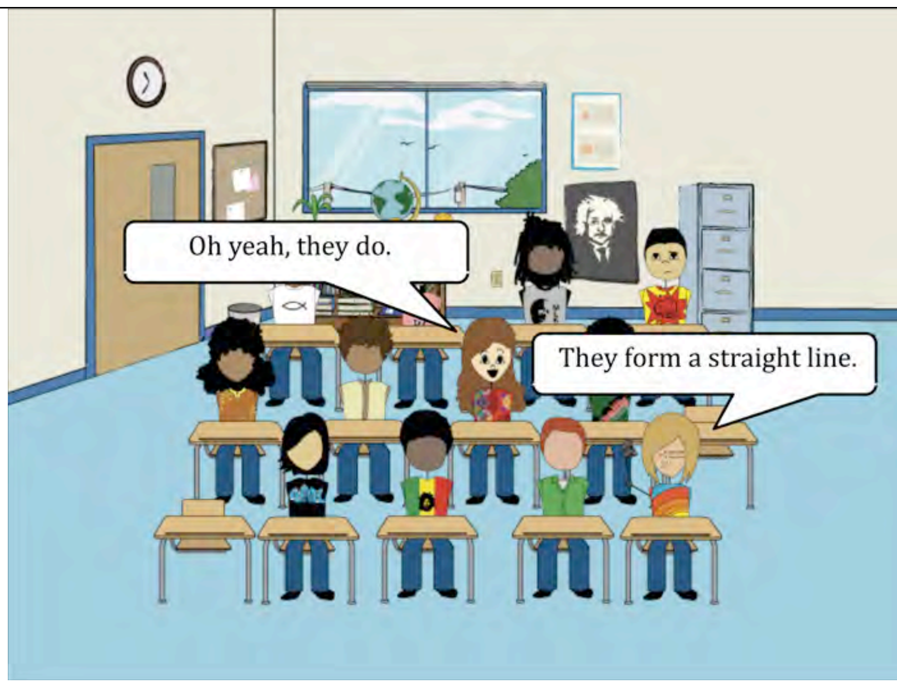


Figure 65. MS-S06: Students react differently to the question.

In the following slide, Slide#7, the virtual teacher, building up from the students' work in graphing and their observation, concluded that there is a relationship between a line and a linear function. And then she introduced the topic of the day—slope, which was identified as the second task in Samantha and Millie's lesson plan.

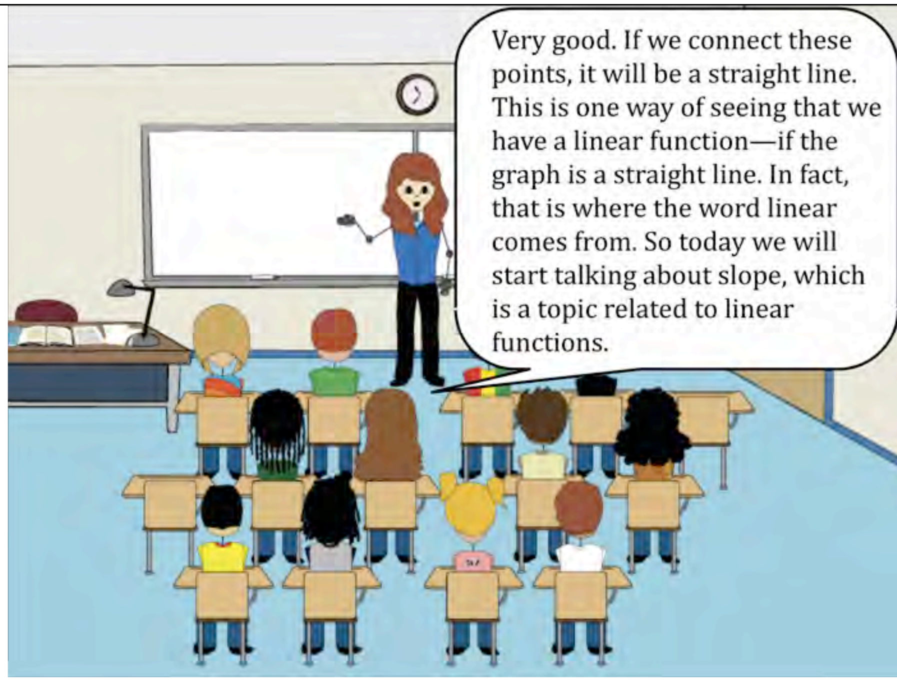


Figure 66. MS-S07: The virtual teacher makes a conclusion and introduces the day's topic.

Analytical commentary on Task #1

The necessary resources for accomplishing tasks became apparent when the pair created the lesson slides. First, when they were developing the virtual teacher's verbal instruction of the graphing task, they became aware that the graph paper given to students should include coordinate axes as an additional resource for the task. Second, the virtual teacher provided an example of graphing a point on the board to remind students how to do the task. Showing an example of how to do a task is a resource for students to better implement the task.

The role of students became visible when the participants depicted the lesson. For example, in response to the virtual teacher's assigned task, the pair decided that students would need to work and that they would need time to do so. Slide #4 showed that several students were writing, indicating they were working on the assigned task. A caption box described that time had passed. In addition, the pair anticipated students' verbal and nonverbal reactions. For example, in the same slide, a student raised his hand and told the teacher that he had finished the task. The pair also anticipated that another student was nonverbally involved, given her confused expression.

The participants' lesson plan gave the teacher a dominant role, but students were actively involved in the task in their lesson depiction. For example, in their lesson plan, the pair only mentioned to have the teacher address that the coordinate points students had graphed form a straight line. However, in their lesson depiction, the pair anticipated a sequence of interactive moves that involved the virtual teacher's prompting questions and multiple students' engagement.

Anticipating Task #2

The second task was not thoroughly planned in the lesson plan. Samantha and Millie intended to have students relate slope to linear function. However, they did not specify what they, as a teacher, would do to help students make connections between these two concepts. They only mentioned that they expected students to apply their daily-life notion of slope and relate it to the graph they had created.

Introduce slope as a topic related to linear functions. Asks students to use prior knowledge of "slope" (as used outside the classroom) to try to figure out the slope of the line or at least to try to determine the relationship between "slope" and the line.

Figure 67. The second task in Samantha and Millie's lesson plan.

From Slide #8 to Slide#11, as planned in the text, the pair intended to help students make a connection between the idea of slope and the line in a graph. In Slide#8 the pair first had the virtual teacher ask students to think about slope from their daily experience. With a student's response in Slide#9, the virtual teacher then, in the subsequent slide, prompted students to think about the slope of the line they had just constructed. In response to the prompt, the pair anticipated that students would make an observation about the relationship between the slope and the steepness in Slide#11.

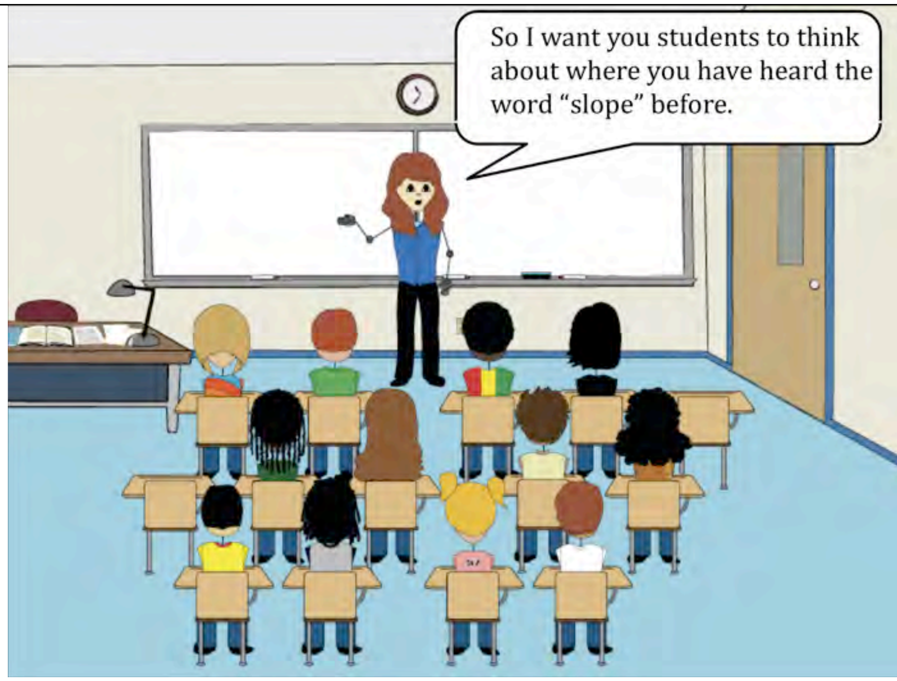


Figure 68. MS-S08: The virtual teacher asks students to think about the slope from daily experience.

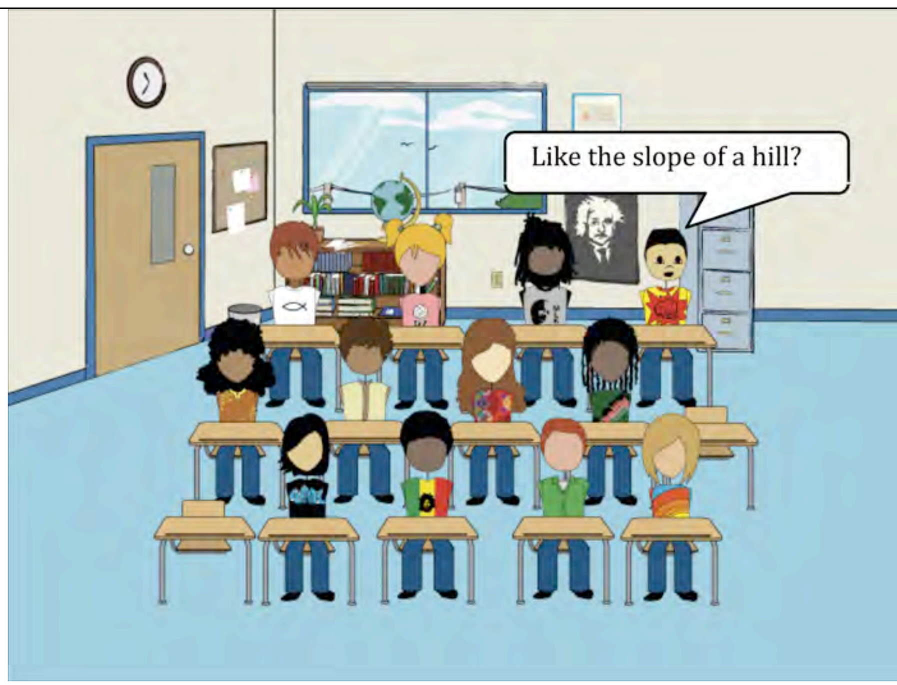


Figure 69. MS-S09: One student gave an answer.

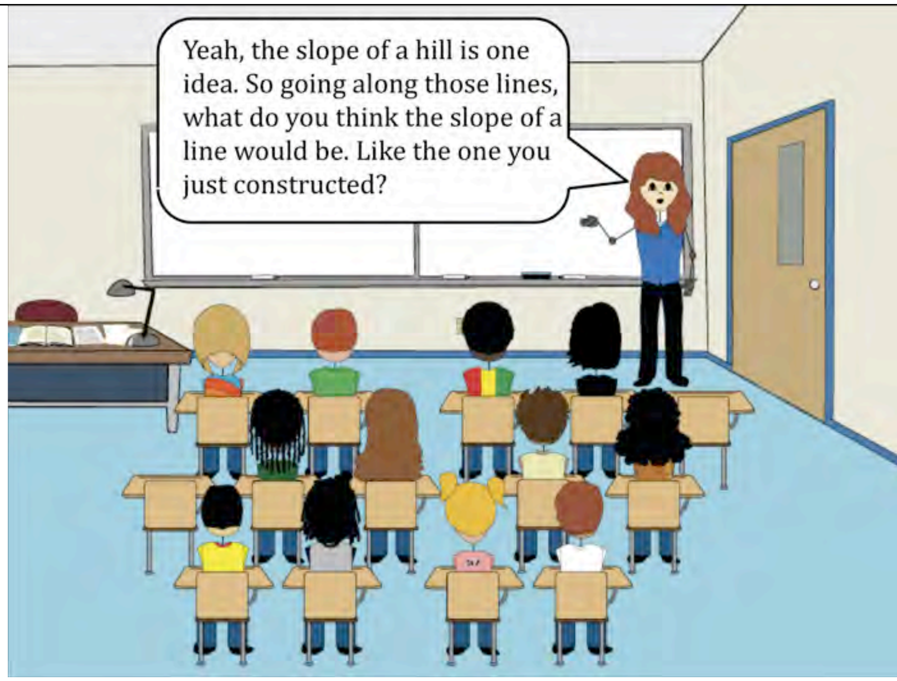


Figure 70. MS-S10-v1[19]: The virtual teacher prompts for the connection between the word "slope" and the graph.

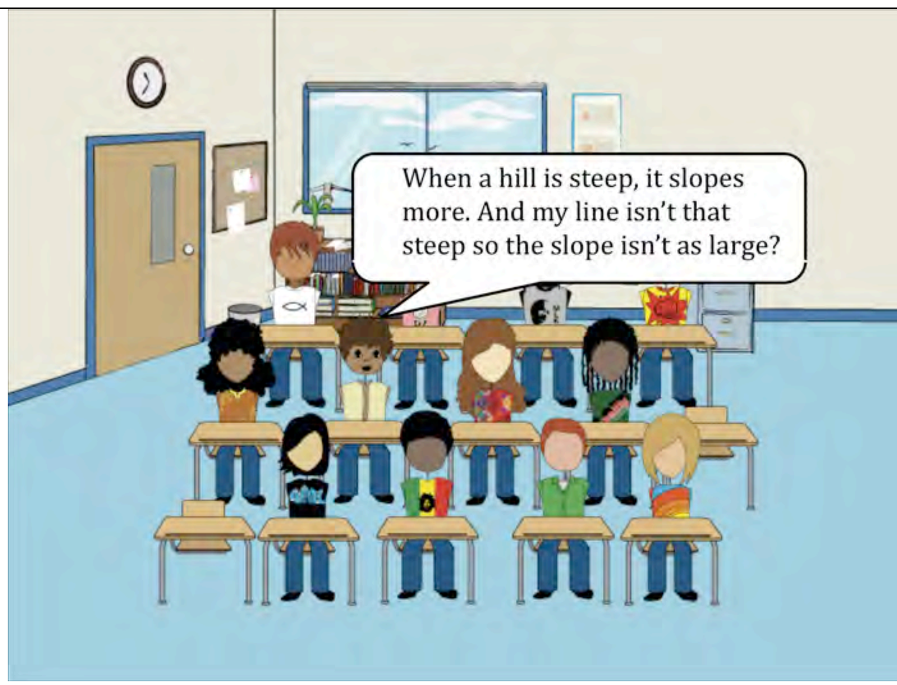


Figure 71. MS-S11: A student makes a connection between slope and the steepness.

[19] The slide was revised later when the pair reviewed it.

Analytical commentary on Task #2

It is unclear from their lesson plan what Samantha and Millie intended to do in the second task. The pair planned to ask students "to use prior knowledge of 'slope'…to try to figure out the slope of the line or at least to try to determine the relationship between 'slope' and the line." However, they did not mention how the teacher would help students to accomplish the task.

In their lesson slides, they specified the teacher's instructional moves and students' responses. They had the virtual teacher discuss with students daily-life notions of slope. Further, the virtual teacher had students to relate slope to steepness. The pair also anticipated what the students would do in the event. The activity of lesson depiction enabled the participants to unpack the teaching event and explicitly anticipate the teacher and students interactions in the lesson.

Anticipating Task#3

The third task in Samantha and Millie's lesson plan was to find the slope from a table. They intended to have students fill a table with the coordinates of points. Then they would ask students to calculate the changes in *y*- and *x*- values and observe the constant ratios. The resources provided for this task were four given points from the previous task. Students would need to fill in the coordinates of these points in a table, calculate the ratios of changes in *y*- and *x*- values, and note that the ratios stayed the same.

Students put their ~4 points into a table. They now have 2 representations (slope and table) of slope. They compute ratios $\frac{\Delta y}{\Delta x}$ and find that they are constant.

Figure 72. The third task in Samantha and Millie' lesson plan.

Following from the previous slide in which a student made a connection between the slope and steepness, the virtual teacher responded in Slide#12 and introduced that the slope of line is the rate of change. She further suggested using a table to observe the rate of change.

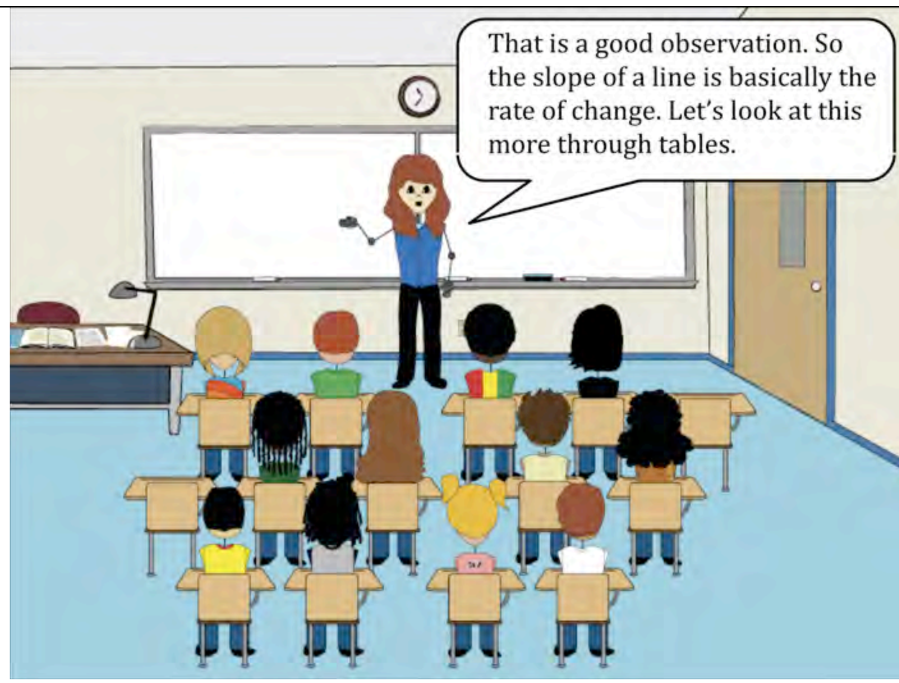


Figure 73. MS-S12 The virtual teacher suggests using a table to better see the rate of change.

The virtual teacher then instructed students to use a table to represent the given four points from the previous task. She drew a double entry table on the board and filled in the first point respectively. Along with the table, the virtual teacher also wrote: "for the point of (2,3)" to illustrate the relationship between the ordered pair of the point and numbers filled in the table. This is to show students an example of how to represent ordered pairs of points in a table format. This can be seen as a resource to help students in accomplishing the task, which had not been mentioned in the pair's lesson plan.

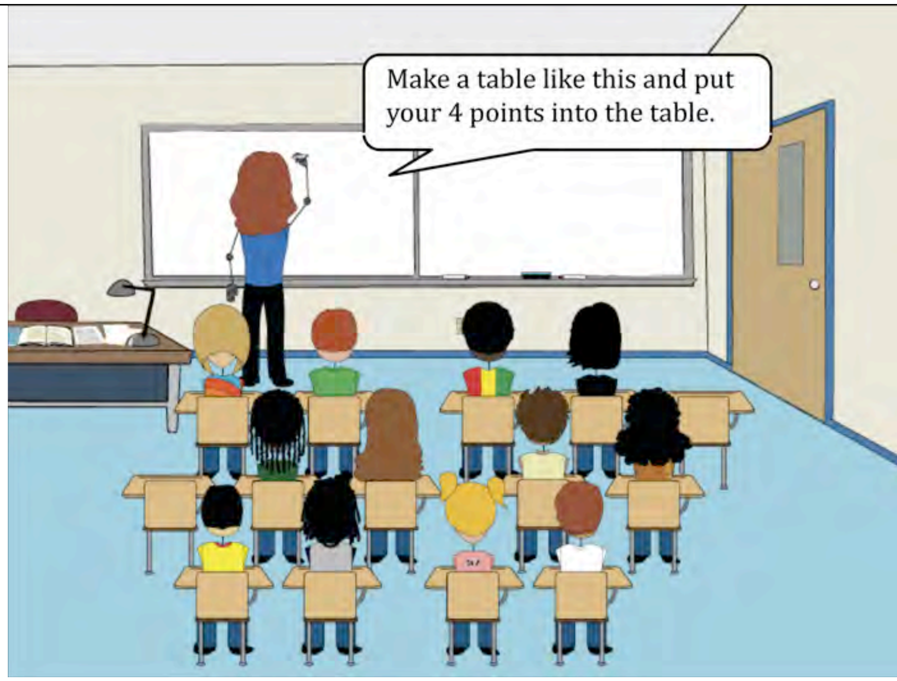


Figure 74. MS-13: The teacher instructs students to follow the example on the board.

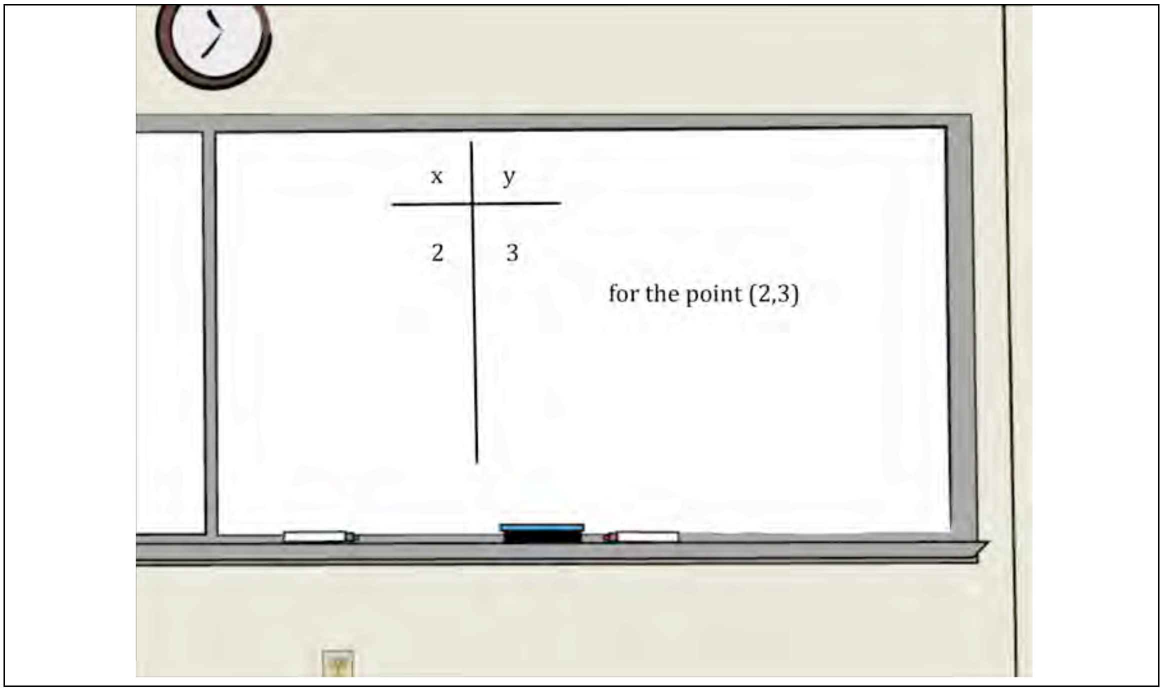


Figure 75. MS-S14: A double entry table with a pair of numbers filled in.

After the virtual teacher assigned the task, the pair created a slide template with a class of students as Slide#15. The pair described that students were working on the task of filling in points in a table format[20].

[20] Samantha edited the wording in the caption box from "The students plot the points" to "The students put the points…"

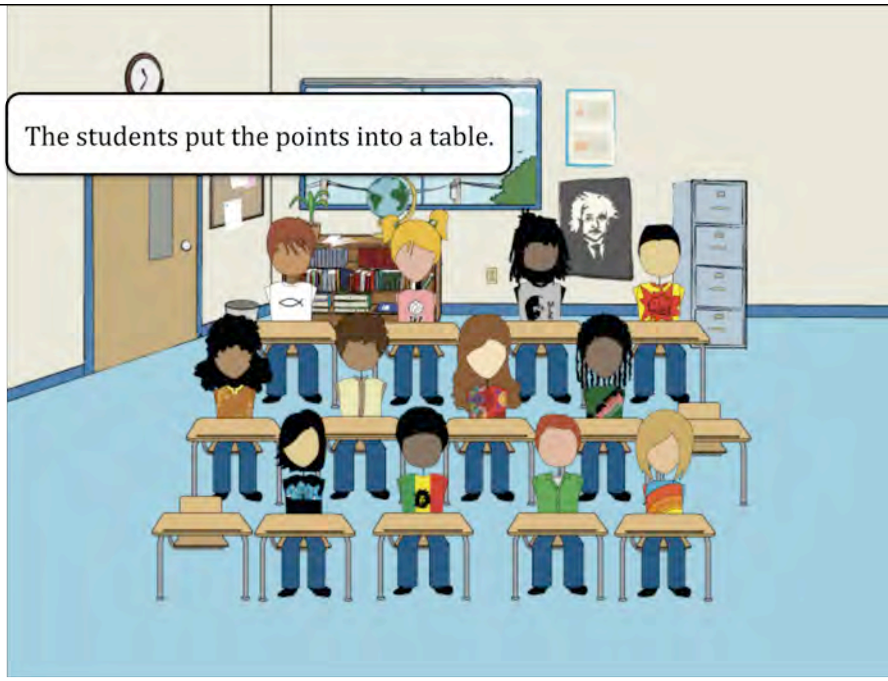


Figure 76. MS-S15: The students are working on the task.

After students had finished the task, the virtual teacher assigned a follow-up task in Slide#16. Millie had the virtual teacher ask students to divide the first y-coordinate by the second and do the same with x-coordinate[21]. However, after she typed it up and the pair viewed the slide together, they found it was better to have students observe the change in *y*- and *x*- values. Hence, Millie revised it to: "Now, working in the '*y*' column, see how much the value changes for each point. Then do the same for the '*x*' column." And then Millie created a new slide with a blank board as Slide#17. In this slide, the table presented earlier was filled with two more pairs of numbers. In addition, the differences between each row in each column were indicated on the sides of the table. This instructional move of showing the points

[21] Here Millie seemed to try to get $x_1/x_2=y_1/y_2$ if the line goes through the origin where y=mx. However, the result of $x_1/x_2=y_1/y_2$ is not the slope. Additionally, it was not clear whether the example shown thus far was the case of y=mx.

and marking the changes in values had not been noted in Samantha and Millie's lesson plan.

In their text, they had intended to ask students to calculate the ratios of change of *y*-value and that of *x*-value. However, to calculate the ratios of two variables, students would first have to find out the change in *y*- and *x*- values. This operation had not been taken into consideration when the pair had planned in the text-based format. In their lesson depiction, the pair developed this instructional move that requires students to calculate the value changes of each point in *x*- and *y*- columns. This move provides an additional resource for students to the following task.

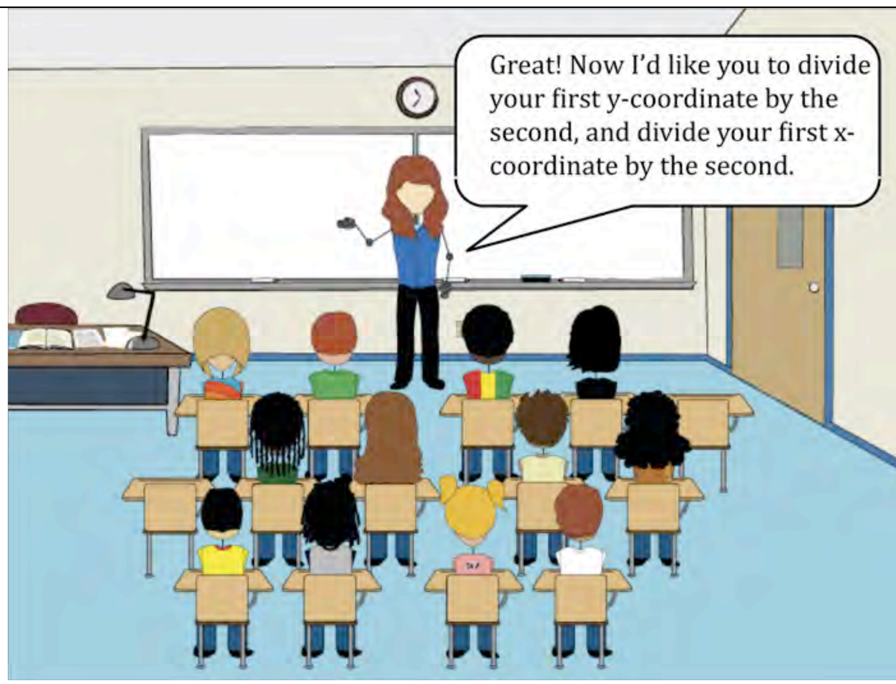


Figure 77. MS-S16-v1: The virtual teacher gave an instruction that was later revised.

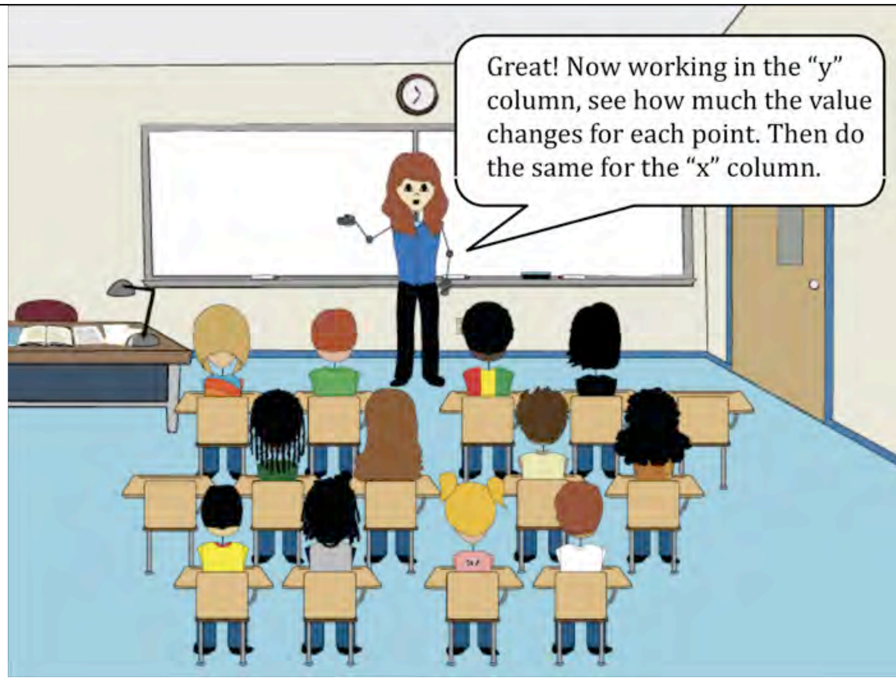


Figure 78. MS-S16: The virtual teacher asks students to find out the change of y- and x-values in each column.

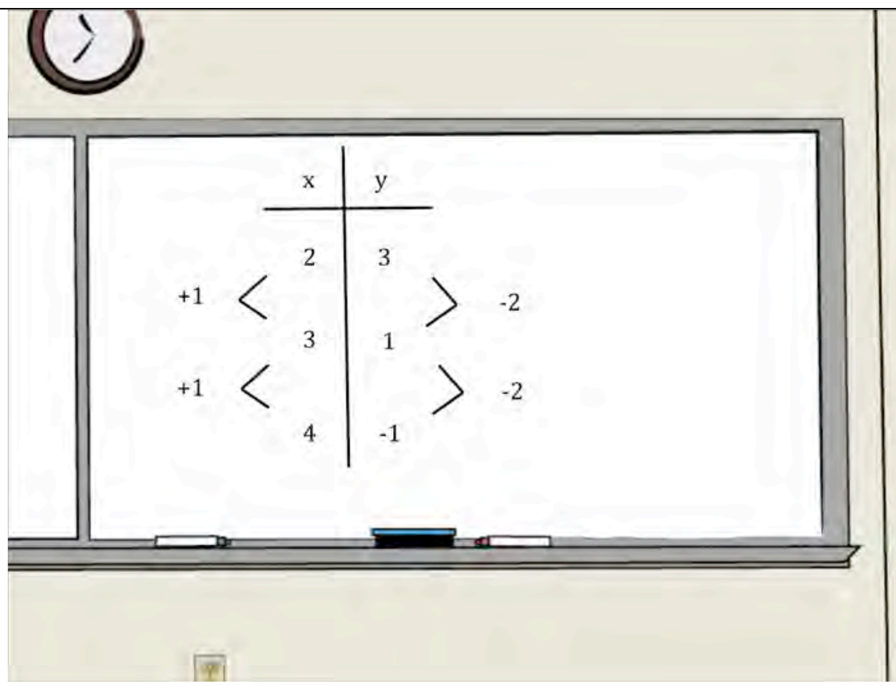


Figure 79. MS-S17: The value changes in each column are shown on the board.

The following slide involves a conversation between a student and the teacher, an event not included in the lesson plan. In Slide#18, the virtual teacher was standing at the center facing the class. A student was asking a question regarding the differences of value changes in each column. He asked: "Do you have to say +1 and -2 like that? Can't you just say 1 and 2?" Then the virtual teacher gave the explanation that the negative sign showed the decreasing values in the *y*-column. The question that the student posed addressed an important concept of changes in slope and illustrated a possible misunderstanding that students may have. This event would not be made possible if the pair were not making the representation of value changes on the board.

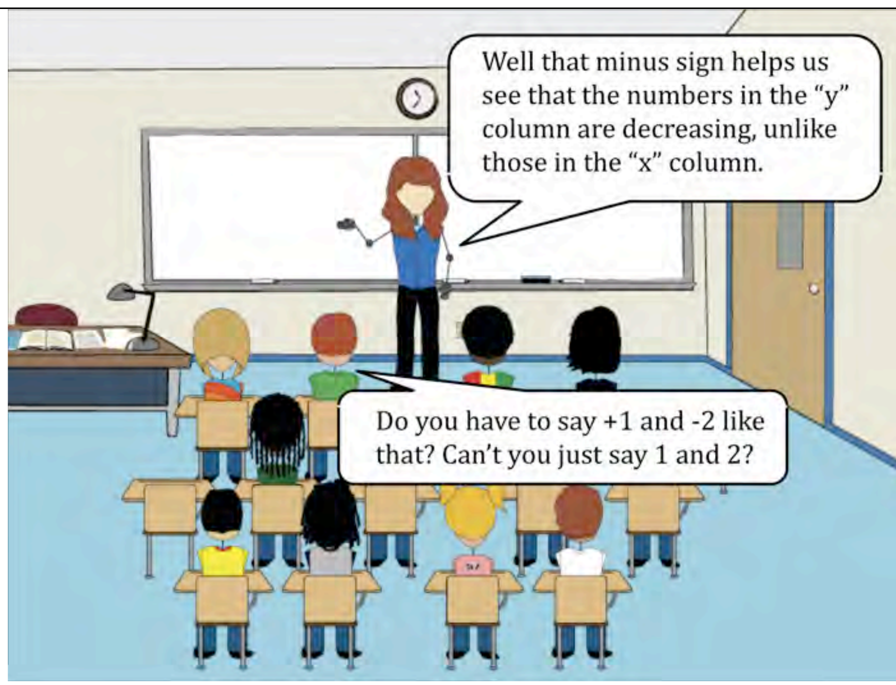


Figure 80. MS-S18: A student poses his question and the virtual teacher responds.

In the following slide, as planned in their text, the virtual teacher asked students to calculate ratios of the value changes in *y*- and *x*- columns. And the teacher further explained that these ratios would be the same. Additionally, a student reflected that the ratio is the slope.

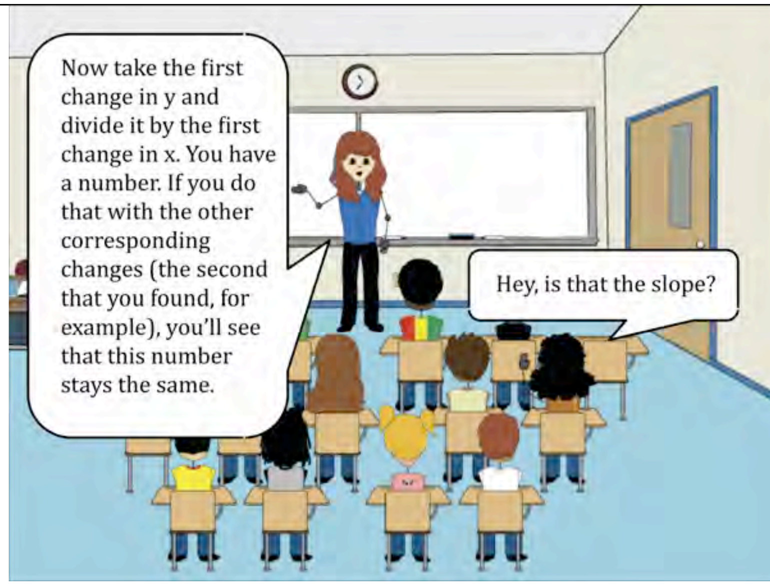


Figure 81. MS-S19-v1[22]: The teacher explains how to calculate the slope with the values previously obtained.

Analytical commentary on Task #3

Similar to Task#1, at the beginning of Task#3, the virtual teacher provided an example of how to enter the coordinates of a point in a double entry table. The teacher wrote the point by its coordinates and entered those in the table. These multiple representations show the relationship between the ordered pair and the pair of numbers in the table. Showing a specific example in different representations serves as resources for students to implement the task. These resources had not been included in the pair's lesson plan.

[22] The slide later was revised when the participants reviewed it.

The participants refined the tasks when depicting the lesson. For example, in their lesson plan, the pair had intended to have students calculate the rate of change among values in the *y*- and *x*-columns. When depicting the lesson, the pair anticipated several intermediate instructional moves that would lead to the task planned in the text. In Slide#16, the virtual teacher first instructed students to work in each column to "see how much the value changes for each point." In the subsequent slide, the differences between each row in the table were marked on the board (see Slide#17, Figure 79).

The activity of creating and viewing the board work allowed the participants to generate the examples they intended to employ in their lesson. In their lesson plan, they mentioned that they would have students graph four points. However, they did not specify which four coordinate points they would give. When composing this lesson slide, the pair was not initially aware of the need to specify them, either. It was not until the next step, calculating the value changes of points, that they generated specific pairs of points.

The activity of creating and viewing the board work allowed the participants to address students' possible misunderstanding and key concepts. For example, after the value changes in *y*- and *x*- columns in the table were shown on the board, the pair identified a key concept. They hypothesized that students might wonder whether there was any importance in noting the value changes with positive and negative signs. Then the virtual teacher had to explain that the negative sign represented the decreasing nature of the change. This teacher-student interaction would not have been possible had the pair not depicted the slide to include the board work.

Anticipating Task#4

In the following task, the pair intended to use graphs to show the changes in *y*- and *x*-values, then to introduce the concept of "rise over run". Further, they intended to address a common error when calculating the slope. The resources utilized in the task could be the graphs that students had created earlier and the ratio that students calculated in the previous task. It is not clear what kinds of operations students would need to perform in the task.

> The teacher utilizes their graphs by showing how the ratio applies (up some amount and over, etc). The teacher explains that the ratio is often called "rise over run", and points out the common error of $\frac{\Delta x}{\Delta y}$.
> Teacher hands out tables and has students graph the line and figure out the slope using the table.

Figure 82. The fourth task in Samantha and Millie's lesson plan.

In the Slide#20, the virtual teacher gave an introduction to "rise over run" and explained what this meant in graph. This piece of explanation had not been included in the pair's lesson plan. When developing the virtual teacher's introduction, Millie first typed in the speech bubble: "Yes, it is! Great thought. We also call this "rise over run", because as you can see if you look at your graph, the change in *y* is how much you are going up or down, and the change in *x* is how much you are going side to side." When viewing the speech, she considered providing a stair example to better illustrate the idea of the change in *y*-values. As a result, she inserted the sentence "kind of like stairs" right after the explanation about change of *y*-values (see Figure 83).

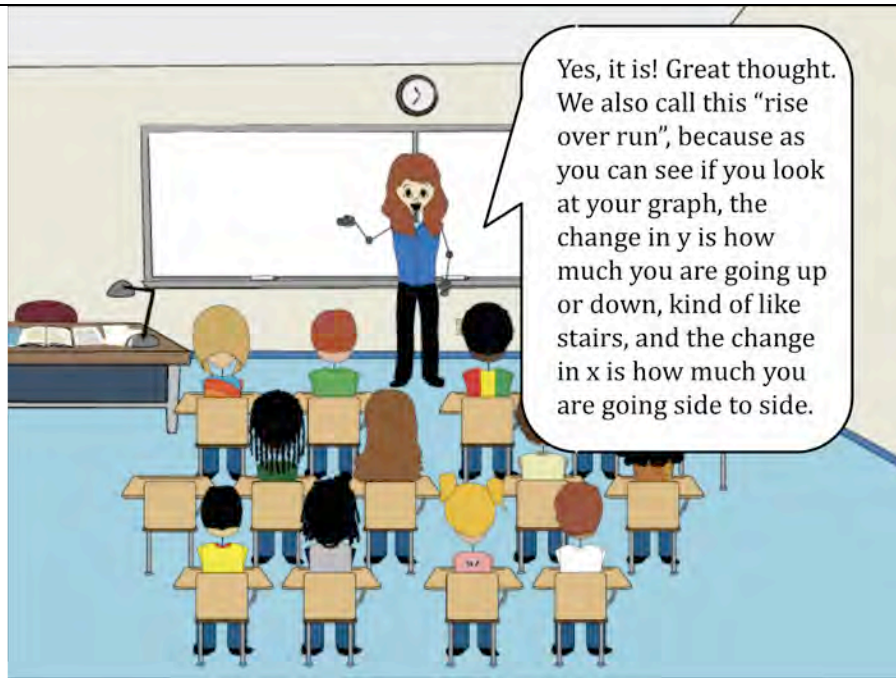


Figure 83. MS-S20: The teacher gives an introduction of "rise over run" with an example of stairs.

In the next slide, Slide#21, the virtual teacher presented a graph with three points connected with a straight line. She also marked the changes in *y*- and *x*-coordinates between points. Along with the virtual teacher's explanation, this illustration of changes in two coordinates is an important visual resource for students to understand the concept of "rise over run." This resource was not mentioned in the pair's lesson plan. Later the virtual teacher reminded students of a common error in calculating slope in Slide#22.

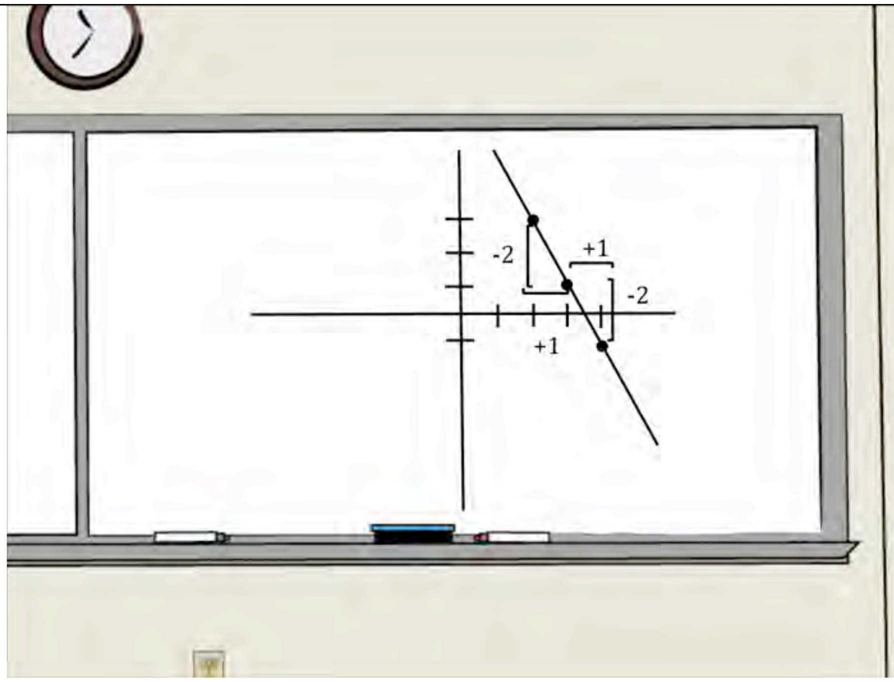


Figure 84. MS-S21: The illustration of changes in y- and x- coordinates helps students understand the concept of “rise over run.”

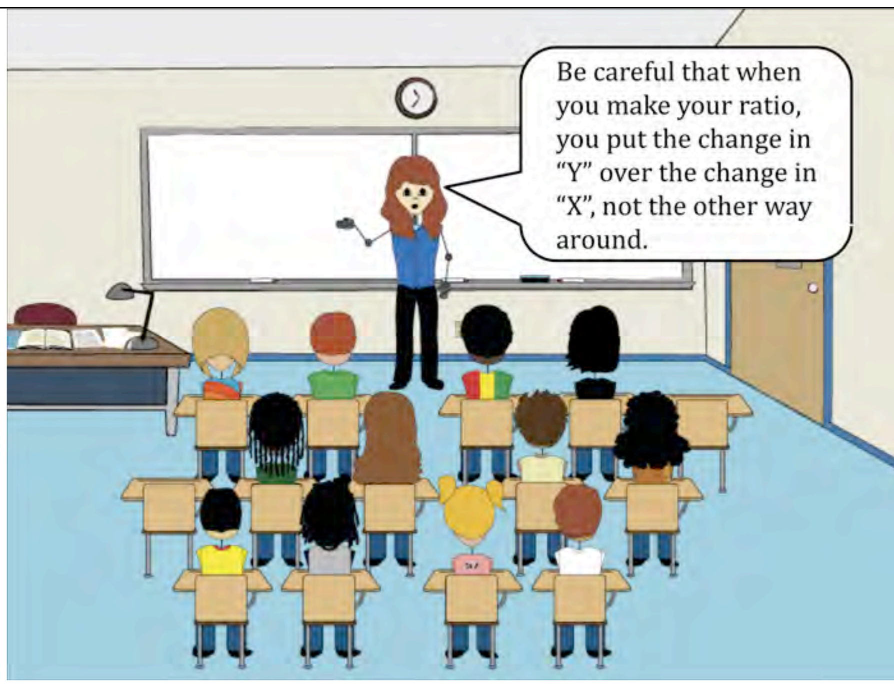


Figure 85. MS-S22: The teacher reminds students of a common error in calculating slope.

In the following slide, as planned in the text, the virtual teacher gave students more problems to practice. They intended to have students practice graphing from given tables and calculating slopes. In the slide, the virtual teacher gave an instruction to the task. And a caption box describes the teacher's action of giving students problems to practice.

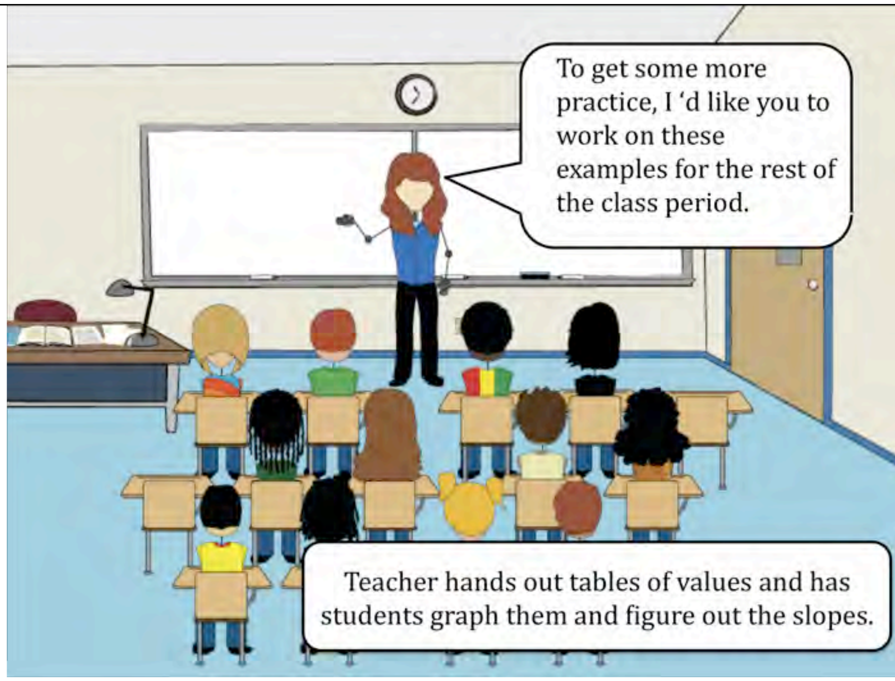


Figure 86. MS-S23: The teacher gives students more problems to practice.

Analytical commentary on Task #4

This task primarily involved teacher's verbal instructions and did not involve much student work. In their lesson plan, Samantha and Millie did not specify how the teacher would explain the concept. Lesson depiction enabled them to make the instructional moves explicit. These instructional moves included verbal and visual explanations that would help students better understand the concept.

In Slide #20, the virtual teacher gives a verbal explanation of "rise over run" with an example of stairs. The virtual teacher also illustrated the changes in *y*- and *x*-

coordinates in a graph as a visual explanation that would enhance students' understanding. These specific instructional moves, providing verbal and visual illustrations, were not anticipated in the pair's lesson plan.

Reviewing slides

When reviewing the slides, the pair made revisions on the virtual teacher's instructions in several places. In Slide #10 the virtual teacher asked an additional question to connect the notion of slope and the graph students just created. The pair changed the wording in two places to make the directions explicitly connected to the work the students had just done (see Figure 87). First, they deleted "So going along those lines" and change it to "So going with that thought." Then they revised the last sentence from "Like the one you just constructed?" to "Like the slope of the line you just constructed?"

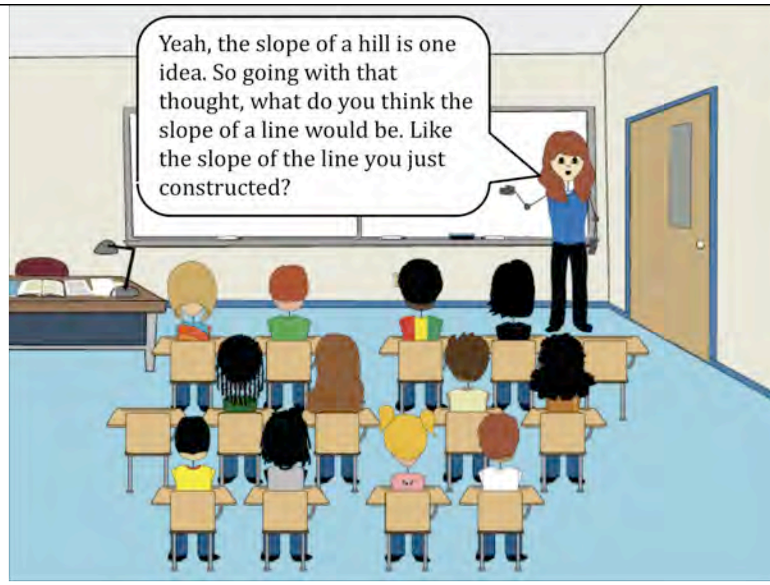


Figure 87. MS-S10-final: The virtual teacher's instruction was revised when the participants reviewed the slides.

When reviewing Slide #19 (see Figure 81) Samantha suggested a revision on the virtual teacher's instruction. The virtual teacher was guiding the students to calculate the ratio of value changes in *y*- and *x*- columns and concluding the ratio the same. Originally, the virtual teacher had given a long description. However, when reviewing, the pair added an example that the class just worked on to illustrate that the ratios obtained from calculations stayed the same.

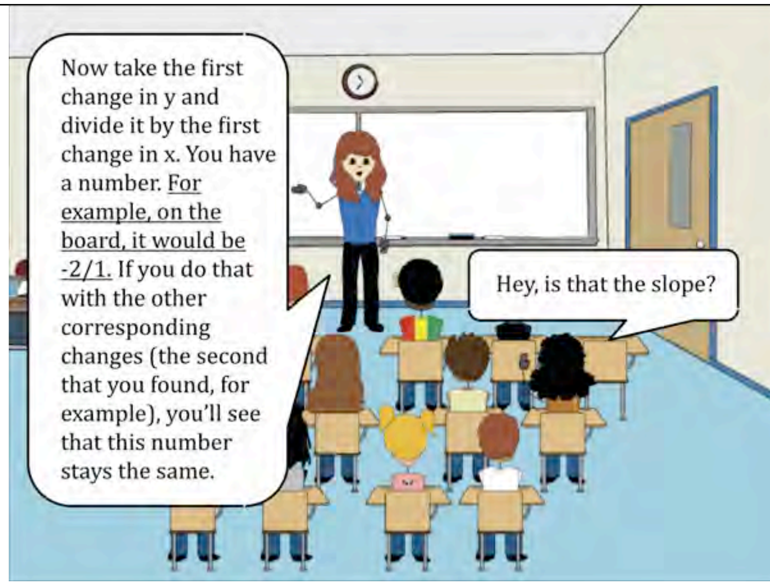


Figure 88. MS-S19-final: The participants revised the slide by adding an example. (The inserted text showed in underline)

The activity of reviewing allowed the participants to articulate the virtual teacher's directions. In Samantha and Millie's case, they intended to make the directions more clearly by strengthening the relationship between the concept and the examples the class had worked on. In doing so, students might better understand teacher's explanations.

Analytical commentary on Samantha and Millie's lesson depiction

Attending to resources for implementing tasks

The pair became aware of providing resources for students to implement tasks. In their lesson plan, the pair had intended to provide graph papers for students to work at the beginning of the lesson. When anticipating the lesson, the pair realized the need to provide the graph paper with axes drawn for students to better work on the task. In addition, when asking students to work on the task of graphing given points on a coordinate plane, the pair demonstrated an example of how to implement the task.

In another instance, the pair also showed an example before students worked on the task. The task was asking students to fill a double entry table with the coordinates of points. The virtual teacher employed two representations to show the relationship between an ordered pair and its representation in a table.

Attending to student participation

The pair became aware of students' participation in lessons. For example, when assigning a task to the class, the pair noted in a caption box that students would need time to work. Consequently, on the slide with the view of a class, several students were depicted writing, indicating they were working on the task.

Besides, the pair anticipated students' verbal and non-verbal participation. For example, in the same slide, while some students were writing, a student raised his hand and expressed that he had finished the task. Another student, however, was confused.

Specifying teacher-student interactions

The activity of depicting a lesson allowed the participants to specify teacher's instructional moves and students' corresponding responses. For example, the second task in the participants' lesson plan was unclear of how the instruction would proceed and how the teacher would help students to accomplish the task.

Refining mathematical tasks

The activity of depicting a lesson allowed the participants to examine and refine the mathematical tasks they intended to implement. The participants refined the tasks when depicting the lesson. They designed several intermediate instructional moves in lesson slides so as to implement the task in the original lesson plan.

Generating specific examples

The activity of depicting a lesson afforded the pair to specified the examples given in a task. In the pair's lesson plan, they intended to have students graph four coordinate points. However, they did not plan the exact points in the task. When initially creating the lesson slide, the pair was not aware of the need either. However, when depicting the subsequent task, calculating the value changes of points, the pair realized the incompleteness of the prior task.

Syntheses of Lesson Depiction across Four Cases

The primary aim of this analysis is to understand the qualities and features of the anticipation of lessons that participants were able to do with the lesson-sketching tool, *Depict*. In this section, I synthesize the analysis across four pairs of participants‘ work in lesson depiction. I examine in what ways the participants attended to instructional issues when depicting lessons. First, I discuss how the participants' image of lesson changed when they depicted it. Then I discuss the instructional issues the participants anticipated in their creation of lesson slides. I adopt the three constructs of the instructional triangle—teacher, mathematics and students (Cohen, et al., 2003) —to frame this later part of the analysis.

The changing role of lesson plan in the lesson depiction activity

The role of a lesson plan changed when participants began to depict their lesson. I found that while they assumed that copying what had been written in the lesson plan would be sufficient, they soon independently realized (from looking at lesson slides, not being told) that their lesson plans lacked detail and that they would need greater elaboration of what would happen in their lessons when depicting lessons. Below I describe how the participants' use of the lesson plan evolved over the course of depicting a lesson.

In planning their lessons using text, pairs of participants had been asked to attend to three elements of instruction by answering three specific questions: (1) What is the mathematics that will be done? (2) What will the teacher be doing? (3) What will the students be doing? Then, four (out of nine) pairs of participants were randomly assigned to the Depict group. In this group, they were asked to implement their text-based lesson by creating lesson slides using *Depict*. They needed to represent their lesson plans with graphic representations, including cartoon-based characters and classroom settings.

The lesson depiction depended upon the content of the lesson plan. Thus, the lesson as planned in both formats (text and lesson depiction) would have no major content differences. However, the analysis shows that these participants attended more thoroughly to instructional issues when depicting lessons than when planning in text.

At the beginning of depicting the lesson, the participants intended to copy what had been written in the text and reproduce it on the lesson slides. They soon realized that they could not do so and began to treat the lesson plans as a reference or framework for their lesson. They then immersed themselves in the teacher role to attend to the virtual teacher's instructional moves, such as verbal explanations and problem representations. They also anticipated students' possible responses. These are all important features of real classroom interactions.

For example, when Ellie and Elliot began to create the first slide in *Depict*, they immediately copied the question the teacher was going to pose from their lesson plan. However, after typing up the question in a speech bubble in *Depict*, they soon realized that they could not just copy it directly; instead, they needed to consider carefully how the virtual teacher would pose a question and how students might respond. Specifically, they realized that they would need to provide a context for the question before actually posing it to students.

This was also the case in Samantha and Millie's work. The first task in their lesson plan had been written: "Teacher gives students graph paper and ~4 (linear) points to plot." Hence, on their first lesson slide, Samantha first typed up the exact same text in a caption box describing the event. However, after viewing the slide, she realized that the virtual teacher should provide students with graph paper and coordinate axes to accomplish the task. She then revised the caption box. In the revised slide, she had the virtual teacher talking to the class: "Class, today we are going to start off with an exercise. I would like each one of you to plot the four points on the axes given to you." This example shows that although this pair had planned the events in the text format, the details of the events concerning how the teacher should address the class were absent in that plan. Only when the participants were depicting the lesson did they attend to these issues.

This shows a major distinction between the two representations of a lesson. A lesson plan does not serve the same role as the lesson depiction. The activity of lesson depiction invites the participants to specifically consider their lesson goals and designs in ways that lesson planning does not.

In the following sections, I will discuss in detail the instructional considerations that the participants attended to in their lesson depiction and that they neglected when planning in text. I first discuss those instructional moves by the teacher that the participants anticipated in lesson depiction. I then identify the modification of mathematical tasks that the participants made, and the ways in which the participants attended to students' thinking and reactions in lesson depiction. Finally, I discuss the temporal factors that were considered in lesson depiction.

Specifying teacher's instructional moves

When depicting a lesson, the participants were engaged in discussing and articulating teacher's instructional moves. The degree to which they attended to those moves seemed to be different from how they had considered them in their lesson plan. They carefully elaborated the explanations and the presentations of problems that the virtual teacher would provide for students, so as to help students understand. They also paid close attention to the representations they provided and the arrangement of the board content.

In the following sections, I discuss the ways in which the instructional moves that the participants attended to and specified when they depicted lessons. First, I describe in what way the participants modified the verbal directions in lessons. Then I show how the participants examined the instructional examples involved in mathematical tasks of their lesson. I also discuss the participants' attention to the presentations of the board work. Finally, I identify the participants' specification of the virtual teacher's behavior in the context of classroom.

Attending to teacher's verbal directions

The activity of depicting a lesson required the participants to develop dialogues between the virtual teacher and students. Since they had not specified the teacher's verbal directions in their lesson plan, the participants spent considerable time discussing how to articulate the virtual teacher's verbal directions when depicting lessons.

In the following sections, I identify three aspects of teacher's verbal directions that the participants elaborated while depicting a lesson. First, the participants became aware of the need to give specific directions for the mathematical tasks they were assigning. Second, they conceptualized the directions and sought explanations that were clear to students. Additionally, they paid close attention to the ways of expressing the directions.

Recognizing the need of giving specific directions

When the participants started depicting their lessons, they intended to employ the tasks as planned in their lesson plan. In their text, they had designed those tasks. They assumed that they would only need to transcribe the question written on their lesson plan as what the virtual teacher would say it to the class.

For example, in Sienna and Pamela's first lesson slide, they typed up the first question of the lesson so that the virtual teacher would say to the class: "How long would it take to walk up 100 stairs?" However, upon reading the slide, they soon realized that the question should include given information; otherwise, it would not be possible for students to answer. Hence, they revised the question to: "How long would it take to walk up 100 stairs if you walk up one stair every second?"

A similar instance occurred in Ellie and Elliot's depiction of lesson. When beginning the depiction, they thought they would only need to copy the teacher's question. However, similar to their colleagues, after typing up the question on the slide, they were aware that the virtual teacher would not pose a question without providing an introduction to the day's topic and a description of the given information. Moreover, they had the virtual teacher demonstrate an example to guide students to better accomplish the task.

Conceptualizing the directions

The work of lesson depiction enabled the participants to conceptualize their directions and discuss what they would say as a teacher to students. In their lesson plans, the participants did not specify how they would do so.

In Ellie and Elliot's lesson plan, they had planned to lead students to graph coordinate points from a given table. However, they had difficulties in providing a good explanation to address the connections between the two variables in the table and the coordinate points in a graph. Finally[23], they decided to lead the students to identify the changing pattern between the two variables in the table and suggested using a graph to better see the changing relationship.

Another example occurred in Beth and Serena's work. They had been planning to show the slope formula and explain the concept of slope. However, they reasoned that the slope formula, $m= \frac{y_2 - y_1}{x_2 - x_1}$, represented by letters, might be too confusing to students. Therefore, they decided to use numbers obtained from an example to illustrate the concept of slope. Later, they considered talking about what students might have known of the idea of "rise over run" when explaining the slope too. Additionally, they intended to give a detailed explanation of the formula. They

[23] In Ellie and Elliot's Slide #8 (see Figure 18), they first had the virtual teacher say to the class: "so, if we think about the number in the table as sets of two point, we can graph these points, right?" After typing this instruction in the speech bubble, Ellie commented that the connection between the "numbers in the table" and "sets of two points" would be confusing. She then suggested introducing the two variables in the table as independent and dependent variables. However, both of the prospective teachers were thinking that this connection was confusing too.

decided to have the virtual teacher write all the related notions of slope on the board (see Figure 55).

Beth and Serena had not planned that way in their lesson plan. Rather, they had intended to introduce the formula first and then to have students practice with an example. However, in depicting the lesson, they anticipated students' possible confusion and decided to explain the concept of slope with related notions. They considered that it would help students better connect what the students have known, the mathematical concept and the calculation of the example.

Enacting instruction by crafting dialogue

When depicting lessons, the participants had the chance to examine what the virtual teacher should say to students. When creating speech bubbles in *Depict*, the participants had to specify the dialogue that the virtual teacher would have with students. This activity encouraged the participants to articulate what to say in the class. And more importantly, they examined whether the word choices were appropriate or comprehensible given students' current knowledge. For example, when Ellie and Elliot were discussing how to direct the virtual students to graph coordinate points from the information in a given table, they paid attention to what would be appropriate to say. The pair thought about addressing the relationship between the two variables from a table and *x*- and *y*- values, and then asking students to "plot" the points. However, Ellie commented that students might not know how to "plot" the point if they had not known the relationship between an ordered pair and the coordinates of a point. They reflected on students' knowledge and noticed the importance of word choices. This instance shows that the activity of depicting a lesson allowed the participants to attend to the proper use of mathematical language. It shares a similar characteristic of "lesson play" (Zazkis, et al., 2009) in which an alternative model of lesson preparation involves designing classroom dialogue. The above instance also shows that the activity of depicting a lesson allowed the participants to approximate teaching practice (Grossman, et al., 2009), specifically in attending to how the teacher should verbally interact with students. Creating dialogues allows prospective teachers to anticipate how to address and explain concepts so as to make them comprehensible to students. This also allows prospective teachers to craft appropriate questions to students and anticipate how students might respond given their current knowledge. Further, it also provides prospective teachers opportunities to plan how the teacher might respond to students' answers or possible questions accordingly.

Clarifying tasks

When depicting lessons, the participants had opportunities to examine the mathematical tasks they intended to show to class. In the following sections, I first discuss the way in which the participants specified tasks included in their lesson plan while depicting lessons. I also show how the participants examined the mathematical appropriateness of the number choices in the examples.

Specifying tasks

When depicting lessons, the participants were aware that they would need to make the task specific. They had not attended to this issue when they had planned using text.

This feature was apparent in Millie and Samantha's work. They intended to have students plot points on graph paper at the beginning of the lesson. However, in the lesson plan, they had not specified what coordinate points to give students to plot. When beginning to depict the lesson, they did not specify the given points either. It was not until they depicted a few slides that they thought about the need for specifying the points to be plotted.

The activity of depicting lessons enabled the participants to specify their task. By designing a task with specific values, the participants had the opportunity to examine the mathematical appropriateness of the task. I discuss the instructional moves afforded by that opportunity in the following section.

Examining the appropriateness of number choices in a task

When planning in text, the participants had not examined the consequences of their assigned tasks. That is, they were not aware of the need to inspect whether the number choices in the tasks were mathematically appropriate. However, when depicting lessons, this instructional issue became apparent to them and they had the chance to modify the tasks planned.

For example, the second task in Serena and Beth's lesson asked students to find the slope of the line through two given points using the formula. Originally, they followed the examples from their text-based lesson plan. In their lesson plan, they had points with identical x and y coordinates. Thus, in the lesson slide, they decided to pick points (2,2) and (5, 5) for students to find the slope. However, they realized that these points were too special of a case that may confuse students: the x- and y-values are identical and the changes in x- and y- values are identical too. Although they noted this example might be easier for students to work on given that it would be their first problem of finding a slope, they concluded that they needed to change the numbers.

It is important to consider the mathematical appropriateness of the examples in a lesson (Mason & Pimm, 1984; Zaslavsky, 2010). Poorly chosen numbers, as in Serena and Beth's original ones, may cause students' confusion and misunderstanding and impede their learning (Zaslavsky & Zodik, 2007). The work of anticipating tasks in lesson slides helped the participants to more carefully attend to this instructional issue.

Examining teacher's written inscriptions on the board

When depicting lessons, the participants would need to specify what to present on the board. This move allowed them to examine whether their inscriptions on the board were correct and appropriate.

For example, when Serena and Beth were drawing a coordinate plane on the board on a lesson slide, they had a discussion about how to present the coordinate plane correctly. They discussed if they would need to label all the unit marks on each axis. They reflected upon the cooperating teacher's advice from their field observation that there is a need to label the unit marks, otherwise, students would think the units did not exist. The activity of depicting a lesson, specifically attending to board work, allows the participants to examine the appropriateness of their board content presentations.

Specifying teacher's behavior

When depicting lessons, the participants identified the virtual teacher's specific moves in the context of the classroom. Given the visualization of classroom scenes in *Depict*, the participants would anticipate the virtual teacher's physical movement or placement.

For example, Beth and Serena commented that when the virtual teacher was explaining the differences between two slopes in graphs, she would walk around and point to the graphs respectively. As a result, in their lesson slides, they had pointing gestures next to the designated graphs to indicate that the virtual teacher was pointing to the graphs while explaining.

When depicting their lesson, Ellie and Elliot specified where the virtual teacher would stand and create the board work. In the second task of their lesson, the virtual teacher involved students in graphing points obtained from a table presented earlier on the board. They realized that the virtual teacher should stand on the right side of the board graphing, given that a table drawn earlier was on the left side. The virtual teacher had to show the table as a reference for the up-coming task of graphing the table.

The above two examples illustrates that the activity of depicting a lesson engaged the participants in an "imagined classroom" (Rosebery, 2005) to anticipate detailed class scenarios. This would help them anticipate more predictable outcomes of lessons.

Refining mathematical tasks

In depicting lessons, the participants had chances to examine the tasks in their lessons. Particularly, they made two kinds of modifications in their lesson slides. First, they became aware of the need for connectivity and transitions of tasks in their lessons and refined the tasks accordingly. Further, they provided various resources for students to accomplish the assigned tasks. In the following sections, I discuss the above two changes that the participants made while depicting lessons.

Seeing tasks as continuous

When planning in text, the participants seemed to list the tasks one by one, and did not think of the connections between tasks. Planning fragmented activities or tasks is a common trait shared with other novices identified in earlier studies (Leinhardt, 1993; Roskos & Neuman, 1995). When depicting a lesson, the participants immersed themselves in the teacher-student interaction, which enabled them to re-examine the tasks and the relationship among them.

Making transitions between tasks

When Ellie and Elliot depicted their lesson, they had difficulties representing two consecutive tasks planned in the format. The first task was for students to read a given table, and the following one was having students graph the table. Ellie and Elliot realized that there was a need to make a transition between these two tasks, in order for students to better understand the relationship between the two representations, table and graph. As a result, the pair had the virtual teacher explain explicitly how to graph points from a given table. Particularly, the virtual teacher stressed the relationship between the variables in a table and the coordinates of points in a graph. This instance showed that the participants recognized the need for the connectedness between tasks and tried to manage this flow in their lesson when depicting it. This instance also illustrated that the participants became aware of the need to make a connection between two symbolic systems. This move is considered essential in expert teachers' instructional explanations (Leinhardt & Steele, 2005).

Integrating tasks

Another way that the participants managed the continuity of tasks was by attending to the relation between tasks and consolidating them when they noticed that adjacent tasks were repetitive. For example, in Beth and Serena's lesson plan, they had the following two consecutive tasks: the teacher introduces the formula of slope, represented by letters; then the students practice calculating slope using the formula with particular numbers. When depicting the lesson, they speculated that the formula represented by letters might confuse students, and thus decided to introduce the formula by way of an example in which they calculated the slope for a particular pair of points. In addition, they had the virtual teacher explain the concept of slope (the ratio of the changes in y and x coordinates for two given points) while applying the formula with an example. This instance showed that the activity of depicting lessons enabled the participants to see the relationship between consecutive tasks. Additionally, they identified the goal for each task and integrate them.

Decomposing tasks

When depicting lessons, the participants would get to realize that the tasks planned earlier in the format were too unwieldy to accomplish and they need to decompose the tasks. As a result, the participants specified intermediate instructional moves to refine the tasks so that the virtual teacher could help students accomplish the tasks step by step.

For example, in the third task in Samantha and Millie's lesson plan, they had intended to have students calculate the ratios of value change of *y*- and *x*-coordinates. They realized that in order to achieve this goal, the virtual teacher would have to first ask students to find out the value changes of both coordinates for each point. This intermediate instructional move showed that the pair decomposed the task when depicting the lesson. While it is identified a common characteristic that novice teachers' planned activities are impractical to accomplish (Leinhardt, 1993), the activity of depicting lessons allowed the participants to refine the tasks and realize them in series of reasonable and manageable instructional moves.

Providing resources for mathematical tasks

When depicting lessons, the participants provided various resources, for the purpose of helping students accomplish the assigned tasks. Below I describe different types of resources that the prospective teachers provided in their lesson slides.

Verbal resources

The participants gave careful thought to the virtual teacher's explanations for the tasks when they were depicting lessons. These explanations were resources that would help students better accomplish the tasks in the lesson.

For example, in Ellie and Elliot's first task in the lesson slides, the virtual teacher provided three sorts of verbal resources for students. First, the virtual teacher gave a context story about the task to problematize the subject matter that they thought might help students engage in the task more easily (Engle & Conant, 2002; Hiebert, et al., 1997). Second, the virtual teacher provided an explanation of the given representation (a table) that might help students better understand the given information. Finally, the virtual teacher demonstrated a way of reading the table that would help students better accomplish the assigned task.

While in the lesson plan, the pair only assigned tasks without considering needed resources; in their lesson depiction they employed verbal directions as resources when assigning tasks. They saw these verbal directions or explanations as guidance needed by students to better complete the tasks.

Visual resources

Visual resources might help students better understand and accomplish tasks. When depicting lessons, the participants made use of board work to specify visual resources for assigned tasks. For example, in their slides, Millie and Samantha represented the changes in y- and x- coordinates both in a table and a graph to help students better understand the concept of "rise over run", a customary way of remembering the concept of slope.

Another example was seen in Beth and Serena's lesson depiction. When explaining the concept of slope, they intended to integrate all related concepts and show them at the same time. To do this, they wrote several different algebraic representations of slope on the board, connected by equal signs. Their goal with this representation was to make connections between prior knowledge and the new formula of slope. The participants attempted to use multiple representations of related mathematical concepts and demonstrated the connectedness among these representations, in order to promote students' understanding (Stein, et al., 2000). The above examples showed that the participants attended to students thinking and gave specific resources that would help students' learning. This is characteristic of instructional explanations (Leinhardt, 1993; Leinhardt & Steele, 2005).

Showing an example of how to do a task

When depicting lessons, the participants would show examples for students to use as resources when working on the assigned tasks. This kind of instructional move had not been planned in text. The participants seemed to realize the need to do so once they had the virtual teacher assign tasks. For example, Ellie and Elliot verbally provided an example of how to read a table with two variables before asking students to do so. Similarly, before asking students to graph points on graph paper, Samantha and Millie had the virtual teacher draw a coordinate plane with a point as an example for students to follow. These examples can be seen as resources that would help students accomplish the tasks.

Specifying material resources

Material resources involved in tasks could support students to work on the tasks. The activity of depicting a lesson allowed the prospective teachers to specify the material resources they would provide for students. For example, at the beginning of Millie and Samantha's lesson, they intended to engage students in an activity of graphing several points given by their coordinates. While depicting this lesson, they became aware of the need to provide graph paper with coordinate axes as an additional resource that might help students in working on the graphing activity. This type of resource became apparent when the prospective teachers were developing the tasks in lesson depiction.

Individualizing students

While in the lesson plan, students were invariable seen as an undifferentiated class, in the context of depicting a lesson, individual students became visible to the participants: They attended to individual students' possible reactions and thinking.

Personifying students

Participants attributed personality to the virtual students. In some cases, they would assign names to students to individualize them. They projected the students' characters from their field observation placement to the virtual ones in lesson slides (Herbst & Chazan, 2006).

In Ellie and Elliot's lesson slides, they had one student answer the virtual teacher's first question regarding making connections between two variables. When moving on to the second question the virtual teacher proposed, they had another student involved in answering the question. However, when composing this lesson slide, Ellie pointed to and commented on the student who just answered the first question: "I bet that kid would probably raise his hand", indicating that the virtual student would also know the answer. It shows that Ellie was aware of students' participation and was personifying the student with the character's grasp of the problem.

The participants would consider customary class interactions they had seen in their field placement and apply these observations in depicted lessons. When Beth and Serena were discussing the content in their lesson slides, they anticipated that it would be the class from their field placement that they would be teaching. Hence, the teacher-student interactions and students' typical reactions in the class were the important references when the pair developed their lesson slides.

For example, when depicting the first task in which the virtual teacher was asking a follow-up question from the previous one, Beth and Serena discussed how the virtual students would respond. They reflected on what had happened in class the week before in their field placement and concluded that none of the students that they knew would have been motivated to answer that question. Then they created a blank slide with a caption box stating: "No student responds to this question posed by the teacher."

Upon completing the depiction of the first task, the pair intended to follow the task as planned in text. In their lesson plan, they intended to give students a brief introduction of the day's topics, including the definition of slope, how to find the slope, and different ways slope is represented. Upon reading the original plan, they realized that the introduction would be too long for students to comprehend it.

However, they reflected that the students in their field placement had been used to hearing long introductions, and decided that the plan would not need any adjustment.

In addition to taking the typical teacher-student interaction into consideration, Beth and Serena named the virtual students after the ones from the field placement and attended to individual students' typical reactions in class. For example, in the pair's lesson depiction, a student they named Mike answered an initial question (see SB-S08, Figure 52). In the following slide, the virtual teacher prompted Mike to elaborate his answer. Beth and Serena discussed what Mike's answer would be and how he would usually behave in the class. Beth suggested that Mike would answer with a little bit of uncertainty. Serena commented, "sometimes he gets apathetic in his answer too." Hence, the pair decided that there was a need to put on a slide that showed the whole class, so they could show Mike's expression along with his answer[24].

Naming and choosing which student to participate in depicting a lesson are similar features in a "lesson play" (Zazkis, et al., 2009). Additionally, the activity of depicting a lesson engaged the participants in considering students' characters involved in their lessons.

Involving multiple students in class activities

While the lesson plan seemed to discourage the participants from anticipating students' participation, the depiction of lessons took the participants to involve multiple students in class activities. In some cases, they would anticipate multiple

[24] This instance also demonstrates that the participants attended to the student's multimodal communication (verbal and facial expression) in class.

students simultaneously responding to one prompt. In other cases, they would involve different students participating in the lesson at different times.

Attending to students at the same moment of a class activity

The participants could see multiple students in the virtual class at the same time. For example, in the second task of Ellie and Elliot's lesson, they had the virtual teacher ask students to predict the traveling distance of a car after ten hours based on some information given on the board. They first anticipated that some students might be puzzled. Then they had one student answer the question. Therefore, in their Slide #6 (see Figure 20), three students showed uncertain expressions, and one student who was sitting in the first row replied to the question. These students' verbal and nonverbal reactions were simultaneously attended to. Another instance appeared in Millie and Samantha's work. At the beginning of their lesson, the virtual teacher gave students graph paper and asked them to graph four given points on a coordinate plane. After the posed task, a slide showed a class of students (see MS-S04, Figure 63). On this slide, several virtual students were seen writing, indicating they were working on the task. Additionally, a student, sitting in the second row, raised his hand and expressed that he had finished the task. This shows the pair identified that multiple students would need to be involved at the moment at which the task was posed. This instance indicates that the participants attended to the simultaneity of classroom events (Doyle, 1986).

Attending to students' participation at different moments

The participants attended to students' participation across time in lesson depiction. They would notice students' participation in the lesson. Hence, when anticipating students' responses, they would consider those virtual students who had not yet participated in class and gave those students opportunities to respond. For example, toward the end of Sienna and Pamela's lesson, the pair discussed what the students' answer would be to the virtual teacher's question. Pamela suggested that the response could come from a student who had not yet participated in class. A similar example occurred in Ellie and Elliot's work. In the third task of their lesson, the pair was discussing a student's possible answer to the virtual teacher's earlier question. They first typed up the answer in a speech bubble at an arbitrary place on the slide. Elliot then suggested that the answer could come from another student who had not yet talked so as to involve more students in the lesson.

Attending to interactions among students

The participants attended to the interactions among students when depicting lessons. For example, in Millie and Samantha's work on the first task in their lesson depiction, they had one virtual student answer a teacher's question. At the same time, another girl from the virtual class agreed with that student's answer. Another example illustrates more interactions among students throughout the lesson. In Sienna and Pamela's depiction, Bob first gave an answer to the teacher's question. However, his answer was not comprehensible to his classmates. One of them, called Susie, questioned Bob's answer. Then Lily tried to explain and clarify Bob's answer. This instance illustrates that the activity of lesson depiction not only encouraged the participants to attend to different students, but also to consider the interactions among them.

Noting students' nonverbal participation

When depicting lessons, the participants were aware of students' emotions and non-verbal reactions in class activities. They showed students' nonverbal responses on their lesson depiction. They had not had this kind of anticipation while planning lessons in text.

Hand gestures were generally applied to two kinds of occasions in the lesson slides. The virtual students raised their hands to show their willingness to answer the questions, or they raised their hands while answering the questions. The virtual students had writing gestures indicating their working on the problem at the moment.

In most cases, the virtual students who were speaking showed neutral expressions. In some occasions, the virtual students appeared confused and uncertain regarding the virtual teacher's questions.

The participants anticipated students' emotions too. They had the virtual students happy or excited when the students solved the problems or grasped the concepts. In addition, the participants anticipated some students to be bored with the mathematics problems and did not show interest in class. For example, in the second task in Pamela and Sienna's depiction, several students were involved in the class interaction: Bob provided an answer to the virtual teacher's question, but Susie was confused. In Slide #5, Lily showed excitement when she was elaborating on Bob's idea. Later, in Slide #6, a caption box reads: "Susie's frustration is gone and now she is excited that she knows how to graph the points from Bob's table." Although this slide did not show students' facial expressions, the description in the caption box indicates that the pair anticipated students' possible emotions and reactions.

In Millie and Samantha's work on the first task, the virtual teacher asked students to graph given points and observe the pattern among these points. In their Slide #6, a student raised her hand and answered the question. Another student sitting in the second row agreed with the answer and showed her excitement. However, another student sitting in the back of the class appeared to be bored.

The participants also anticipated nonverbal responses not available in the *Depict* tool. Sienna and Pamela created an expression to better represent a virtual student's thought. At the beginning of the lesson, the pair was depicting that a student was thinking that the teacher's question was too easy. Pamela and Sienna commented that the student was thinking, " 'duh', this is obvious." This example shows that the participants are sometimes capable of anticipating students' unspoken thoughts even without graphic prompts that encourage them to do so. Of course, the general properties of *Depict* enable teacher initiative, even when it doesn't direct it. It also shows that the participants anticipated students' thinking along different lines that while some students were thinking about how to answer the question, others might be thinking about the nature of the question itself.

Hypothesizing students' thinking

When depicting lessons, the participants were able to attend to students' thinking. For example, they speculated what the students' answer might be, students' confusion, students' difficulties in understanding given what they hypothesized would be their current knowledge. This differs from the lesson plan in which individual students' actions, such as their possible responses, emotions, thinking, or learning difficulties were rarely addressed (in spite of the fact that they had all already looked at and annotated students' individual work on linear function problems).

Anticipating students' uncertainty, difficulties, and confusion

When depicting lessons, the participants anticipated some possible uncertainties and incorrect responses from students. Additionally, the participants considered students' possible difficulties in accomplishing the assigned tasks. However, this kind of anticipation was not addressed in their lesson plans.

For example, Ellie and Elliot hypothesized that the task they assigned might be too difficult for students to answer given their prior knowledge. But the pair recognized that some students might be capable of doing something easier related to the task. Consequently, in their lesson depiction, they had several students with confused expressions and a student replied with the observation of given information without a direct answer.

Samantha and Millie hypothesized students' possible confusion in their lesson. In the third task of the lesson, the virtual teacher had students calculate the value changes of x- and y- coordinates and then presented the work on the board. The value changes involved the increase and decrease of values, thus being presented with positive and negative signs with numbers. Samantha and Millie hypothesized that students might be unsure of the differences between the increase and decrease of values. A student asked, "Do you have to say +1 and -2 like that? Can't you just say 1 and 2?" Then the virtual teacher addressed the concept of the increase and decrease of values. By anticipating students' possible questions, the participants were able to address the important issues of tasks in their lessons.

Hypothesizing students' prior knowledge

When anticipating students' possible responses to the assigned tasks, the participants would need to consider and have discussion regarding students' prior knowledge and their capability to respond to the tasks. Although in this study, the participants did not have a thorough understanding of students' prior knowledge for each task, they did become aware of this important aspect in anticipating students' possible responses.

For example, while Ellie and Elliot were depicting their lesson, they constantly had discussion regarding students' prior knowledge. They hypothesized that students would know how to observe the value-changing pattern from a given table. When discussing how to explain the connection between the table and graph representations, Ellie commented: "I don't know. It's hard when you don't know what the kids know (Turn 295)." They had difficulties in designing this instructional move because they did not have a full grasp of students' prior knowledge. It showed their awareness of the need to attend to students' prior knowledge.

Considering temporal factors in a lesson

Temporal aspects of a lesson became more apparent when the participants depicted their lessons. Although they were asked to estimate how long each segment of a lesson would take when planning in text-based format, the participants generally underestimated the time required. Moreover, they were not aware of the need to allocate time for students' responses to a teacher's request. That is, they would need to allow a period of time for students to work on the problems the teacher proposed.

In Samantha and Millie's lesson slides, they showed consideration of time needed for students to work, which was missing in the lesson plan, in spite of being prompted. In their slides, after the virtual teacher posed a task to the class, Samantha and Millie used a slide template that showed the class of students. On this slide, they assigned several students writing gestures, indicating the students were writing and working. On the bottom left corner of the same slide, a caption box was to read: "After a couple minutes of working," indicating the time given to students to work on the task.

Ellie and Elliot attended to the same issue in their lesson depiction. In their slide #5, the virtual teacher was posing a question that required students to read information from a given table on the board. After composing this slide, Ellie commented: "I think they would think about it for a while." This comment was not, however, acknowledged on the slide. It was not until reviewing a set of slides created thus far that they created a caption box on the upper right corner of the slide, stating: "After a few moments." It showed that time had passed and students were given time to think about the question.

Although the participants did not show their capability of estimating time precisely in lesson depiction, they showed that they were at least aware of the fact that students would not be able to complete the assigned tasks instantly. Instead, students would need time to process thinking, and the teacher had to anticipate this issue in planning their lesson.

Conclusion

This chapter has described the features of lesson anticipation using *Depict.* While the participants' considerations of instructional detail were generally missing in the lesson plans, they were able to attend to issues in instruction.

Regarding teacher involvement in instruction, the participants specified teacher 's instructional moves when depicting lessons. They were engaged in discussing and articulating the explanations and the presentations of problems that the virtual teacher would need to provide for students, so as to help students understand better. They also paid close attention to the representation and the arrangement of the board content. The degree to which they attended to these moves seemed to be different from how they had considered them in their text-based lesson plans.

Regarding the mathematical work involved in a lesson, the participants refined the mathematical tasks so as to make them manageable and feasible to accomplish. When depicting lessons, the participants came to view tasks as connected and realized the need for making transitions between those tasks. In addition, they were aware of the need of intermediate steps to make the tasks manageable for students. Further, they provided resources (verbal, visual or material) for students to work on those tasks.

Regarding student involvement in instruction, the participants individualized students and anticipated students' possible thinking and reactions. While in planning in text, there was little student involvement in lessons, individual students became visible to the participants when they depicting lessons. They attributed personality to individual students and hypothesized students' questions and confusion. Further, the participants anticipated students' nonverbal participation.

Overall, the participants using *Depict* unpacked general descriptions of teaching into moment-to-moment teacher and student interactions around mathematics in instruction. The participants specifically attended to teacher's instructional moves, students, and mathematical tasks.

CHAPTER 6

USE OF DEPICT'S FEATURES

In this section, I address Research Question #3: How do prospective teachers employ the graphic resources to support their lesson depiction? I discuss what the lesson-sketching tool, *Depict*, afforded the participants in anticipating lessons. Particularly, I discuss how the participants made use of the tool's features to attend to instructional moves while depicting lessons. Additionally, to examine the affordances of visualization of lesson slides, I also identify the actions that the participants took while interacting with *Depict* that allowed them to attend to the details of their lessons in ways they had not in the lesson plans.

Use of Graphic Features

Templates

Depict includes templates of classroom shots. In this study, these were static templates; specific characters were assigned to specific locations in the room, with all students sitting in rows and columns, and users could not add characters or shift their locations[25]. Users could choose a template as background for each slide from six available templates that differed amongst themselves by the location of the camera (and thus what part of the class was visible). Four templates provided a

[25] A later version of *Depict* has more flexibility in adding characters and assigning their location, see Lessonsketch.org and Herbst & Chieu (2011).

view of a teacher who was seen standing at different locations, writing on the board, or talking to the class. Another template provided a view of the students' faces. The last template was a close-up shot of a blank board that allowed users to present board content. While this template could show a close-up shot of board content, the templates with view of teacher also included a blank board and allowed users to present board work.

Participants composed a total of fifty-four slides to depict the lessons that they had planned in text. Among those, thirty-four slides offered a view of the teacher. Twelve slides showed view of students. The majority usage of teacher-centered templates shows that the teacher role dominated these participants' lessons. At the same time, it is notable that the participants did anticipate students' responses because they represented them using the student-view template.

Six other slides were shown with close-up shot of board work. Regarding the board work in lesson depiction, although there were only six slides with close-up shots on the board work, fifteen other slides showed board content on the templates with view of teacher.

Two other slides were represented using no template and instead using a blank background over which participants wrote descriptions of class activities. A blank page was not initially one of the designed templates. However, the participants made use of blank pages to describe class events that did not necessarily require representation with graphic background.

Table 6.1 Use of Templates and Actions on Templates

		Creating a background		**Changing a template**	**Total**	
		Selecting a template	Duplicating a previous slide			
View of teacher	View of teacher (no board content)	19	0	0	19	Total: 34
	View of teacher (including board content)	5	6	4	15	
View of students		11	0	1	12	
Board		6	0	0	6	
Blank page		1	0	1	2	
Total		42	6	6	54	

Actions on templates

I identified two major actions that the participants took on templates while depicting lessons. In what follows, I will define these actions and discuss what I observed participants doing.

The first category of action, *creating a background*, describes each of two possible actions in *Depict*. One is *selecting a template* (from the given ones) and the other is *duplicating a previously composed slide*. The former refers to how users would start to compose a new slide from scratch: They clicked a pull-down window on the right hand side of the *Depict* canvas, choosing one template from a collection of templates, and dragged this template onto the canvas. The majority of the creation of lesson slides fell in this category.

Another action classified under *creating a background* consists of *duplicating a previous slide*. Users could choose to duplicate a composed slide in order to retain all its graphic elements. They could afterward make piecemeal changes (e.g., change of board content). For this study, I only identified those duplicated templates that were kept in the final sets of lesson slides. That is, a duplicated slide that got deleted in the process of lesson depiction was not counted.

The participants as a whole did six duplication of slides. Of these six duplicated slides, all included a view of the teacher; these slides also had board content. This suggests that the participants made use of this feature to preserve the graphic features, especially the board work, and carried them over to the following class activities. The participants were aware of the board work as resources for the subsequent class events.

There was no duplication of slides with view of the students. This may be explained by the possibility that the participants, with little to no teaching experiences would initially ignore student responses. Although the study shows that the participants anticipated students' responses using the template with view of students, they only expected brief student involvement. A possible explanation is that the participants assumed students' engagement only occurred when they would need to follow the teacher's lead and would not dominate the class for a longer period of time.

The second category of action, *change of template*, refers to the action whereby users replace a selected template and depict class events on the replaced one. The category *changing a template* describes each of the following possible series of actions:

The first series of actions includes selecting a template, deleting it, and then selecting another template. The second series of actions includes duplicating a previous slide, deleting it, and then selecting another template. The third possible series of actions includes selecting a template, moving it down the stack of slides, and then selecting another template. The final possible series of actions includes duplicating a slide, moving down the duplicated slide, and then selecting a new template. When finally staying with a desired template, users may choose to duplicate a previously created slide to retain the graphic background or select a new template from the pull-down window in the tool.

There were six incidents of changing a template while the participants were depicting lessons. Among these six incidents, two-thirds occurred when the participants replaced the template background with board work. That is, they attended to the need to continuously show the board work created in an earlier activity. For example, they changed the virtual teacher's physical placement in order not to block the board work—They did that by changing the template with the virtual teacher standing on the left side of the board to another template in which the teacher was standing on the right side.

Other instances of changing a template could attest to the participants' attention to students' reactions. The participants tended to select a teacher shot or duplicate a previous teacher-shot slide for the subsequent event. However, when viewing a template focused on the virtual teacher, they might realize the need for students' reactions in the subsequent event. This would explain why the participants would move down the selected template, indicating they would save it for later. They then selected a new template with the view of students or selected a blank slide describing students' responses.

Speech bubbles

Users of *Depict* can add speech bubbles to the cartoon characters to represent the dialogue between teacher and students. In specifying the dialogue, the participants would need to elaborate the virtual teacher's explanations and instructions and consider possible student responses. I hypothesized that the speech bubble feature would support users' attention to details concerning subject matter and student thinking.

The right end column in the following table (see Table 6.2) summarizes the number of occurrences of speech bubbles in the lesson slides. In fifty-four lesson slides, fifty-seven speech bubbles were created to represent either teacher or students' discourse. Among these speech bubbles, the number of speech bubbles for the teacher was approximately one and half times the speech bubbles for students.

Table 6.2 Use of Speech Bubbles and Actions on Speech Bubbles

	Creating	**Dragging**	**Editing**	**Formatting text**	**Total**
Teacher's speech	23	0	12	1	36
Students' speech	16	3	2	0	21
Total	39	3	14	1	57

Actions on speech bubbles

I identified four types of actions that users would take while using speech bubbles in lesson depiction. The first type *is creating* a generic speech bubble. The second is *dragging*, an action of the re-assigning a speech bubble from one speaker to another. A third is *editing*, an action of revising content in speech bubbles. The fourth type of action is *formatting* the writing of the contents of the speech bubble.

The first type of action on speech bubbles is *creating*. Users have to click on a "speech bubble" button on the right hand side of the canvas and a speech bubble will appear on the template. Users then need to type in text to create the virtual teacher's or students' discourse. To distinguish this type of action and the other actions on speech bubble, I further define the creation of speech bubble (similar to that of a template) as an action that does not involve any other action, such as content change, once the speech bubble is created. From the analysis, approximately two-thirds of speech bubbles were created and with no other actions involved.

The second type of speech bubble action, *dragging*, refers to moving a created speech bubble from the current character to another one. This action happened only on students' speech bubbles. It may imply that the participants were viewing multiple students simultaneously and dragged the speech bubble around to assign the responses to the students they thought would speak at that moment. In some instances, the participants commented on their dragging of speech bubbles to reveal their intention to involve more students in class activities.

The third type of action, *editing*, refers to how users revise the content of speech bubbles they have already created earlier. This action may be observed from several possible behaviors. Users may delete all content in a speech bubble and re-create new content in that speech bubble. Users may insert words or sentences in the existing content. Additionally, users may remove the words or sentences they consider redundant. Users may also modify word choices.

Fourteen instances of editing on speech bubbles occurred in this study. The majority of these actions were aimed at revising the virtual teacher's speech. Editing mainly happened right after the participants read through a current speech bubble. Among those incidents, two instances of editing occurred when the participants were working on the first speech bubble they had ever created. From the other analysis of this study (see Chapter 5, Case #1 and Case #2), these two instances occurred when the participants intended to copy their lesson plan when beginning to depict the lesson. However, after typing up the virtual teacher's initial question to the class, they found that they had not given enough detail in the virtual teacher's verbal instructions.

Editing also occurred when the participants reviewed a set of lesson slides they had composed that far. They modified the word choices or articulated the virtual teacher's verbal expressions.

The fourth type of speech bubble action is *formatting text*. The formatting function provided in the tool thus far was limited to capitalizing characters in text. This action occurred once in the study while the participants capitalized certain letters in the speech bubble to indicate emphasis that the virtual teacher would make in her speech (see Case #4, Millie and Samantha's work, Slide#22 and related discussion). It may imply that the participants attended to how the teacher's verbal messages would be delivered in the real-life situation. It also supports the hypothesis that lesson depiction encourages prospective teachers to anticipate in detail how their lesson would unfold.

Inscribe

Inscribe is a board writing and drawing tool embedded in *Depict*. It allows users to create board work for lesson slides. Users create background-transparent inscriptions using *Inscribe* and then attach those objects to slides, placing them on the white board or on students' sheets. In this study, the participants made use of this tool to present mathematics problems to students or anticipate students' work.

I identify three types of actions the participants performed with *Inscribe*. The first type of action, *creating new objects*, refers to when users open *Inscribe* and use any of the features, such as drawing a line or typing text, to produce an object they intend to show on the board. In this study, a majority of participants' actions in *Inscribe* fell in this category.

The second action I identified is *editing*. It refers to users' addition of elements to or modification of an inscription already created. When users create the board work, they have a chance to view the work either in *Inscribe* or after attaching it on the board on the templates. Therefore, the action of editing may occur when users are viewing the currently created object in *Inscribe* before attaching it to the blank board, or when users are viewing the object from the board.

Table 6.3 Actions in Inscribe

Actions in Inscribe	**Number of occurrences**
Creating new objects	11
Editing	4
Attaching a pre-created object	1
Total	16

The analysis shows that four editions are done. The *Inscribe* tool allowed the participants to specify and examine the written inscriptions and mathematical representations they intended to show in their lessons. For example, from Case #2, in Sienna and Pamela's lesson slides, they created a graph they hypothesized a student would draw on the board. However, when viewing it on the slide, the pair found that they did not label the two axes. They then wrote "x" and "y" on the two axes and additionally labeled the two variables. To do so, they argued, would help clear students' common confusion of x and y axes.

Further, the tool allowed the participants to inspect the mathematical appropriateness of the mathematics problems they intended to adopt. For example, in Beth and Serena's lesson slides, they created a graph with two coordinate points as an example adopted in their lesson. However, when viewing this example in *Inscribe*, they thought the number choices in this example were too special as cases and so they might confuse students. As a result, they modified the example.

The third type of action in *Inscribe*, *attaching a pre-created object*, refers to an action that users performed when they attached a previously made object, stored in *Inscribe*, to a newly composed slide. This occurred only once: when the pair of participants attached a set of graphs (two coordinate planes), drawn earlier on the board from the previous slide, to the current slide in which the virtual teacher posed a question regarding this set of graphs. This action shows that the participants were aware of the need to show the board work consistently and identify the board work as a resource for the assigned task. Although this type of action only happened once in the study, the participants made use of another feature, duplicating slides, to carry the graphic elements to the next slides (see related discussion in Template section).

Caption boxes

The caption box is a feature that allows users to describe events or note other information that may not be possible to convey through existing graphic elements. In this study, the participants employed this feature to represent various kinds of events or objects in their lessons. Eighteen caption boxes were presented in the lesson slides.

I differentiate these caption boxes according to how they related to the temporality of events reported: Captions were classified into past, current and future events. Seven caption boxes described events about what had happened in the past, such as “the student came to the board and returned to his seat.” In addition, there were seven caption boxes that showed events about what was happening in the present. For example, a caption box described a student’s unspoken thoughts at the moment. Finally, the participants made use of caption boxes to specify future events in their lessons. For example, in Samantha and Millie’s last slide, a caption box described what would happen after the virtual teacher introduced the class a follow-up activity: “Teacher hands out tables of values and has students graph them and figure out the slopes." Four instances of this category were observed.

Table 6.4 Use of Caption Boxes and the Content Revealed in This Feature

	Past event	Current event	Future event	Total
Teacher action	1	1	1	3
Student action	5	4	1	10
Teacher & Students Interaction	1	0	2	3
Board work	0	2	0	2
Total	7	7	4	18

I further examine how the participants utilized caption boxes to describe teacher and student involvement in class events. Among the eighteen caption boxes used in this study, over half were used to describe students' actions. Besides, three more caption boxes were used to indicate teacher and students' exchanges in class. The other three were used only to describe the teacher's actions. Caption boxes were also employed to show the current content on the board. For example, the participants wrote "table" in a caption box on the board to indicate that a table shown in a previous slide was still present.

From this analysis one can observe that the participants mainly employed caption boxes to describe students' involvement in class activities. This provides evidence that supports the hypothesis that participants could anticipate and attend to students' possible behavior or reactions in their lesson depiction, an attribute not apparent in their lesson plans.

Actions on caption boxes

Caption boxes seemed to be used extensively for describing class events involving teacher and students characters. However, over one third of the caption boxes were not created at the moment the participants first composed the slide where they would eventually be placed. I identify three major actions that the participants made to include caption boxes on the lesson slides.

Table 6.5 Actions on Caption Boxes

Actions on Caption boxes	Number of occurrences
Editing a caption box	4
Adding a caption box	2
Dragging a caption box	1
Total	7

The first action, *editing*, refers to users' modification of the content in the caption box. In four instances, the participants refined the content of caption boxes to make the event descriptions explicit. For example, a pair of participants described in a caption box that the virtual teacher was giving students graph papers to accomplish a graphing task. When they were viewing this text, they edited it to include coordinate axes in the graph paper. This instance shows that the participants included more detail in their class event when viewing the slide. They provided specific resources for students to complete the assigned task.

The second action, *adding a caption box*, occurs when users create a caption box after they have finished composing a slide, have begun composing the following slide, and then return to the preceding slide. Therefore, the creation of a caption box on a slide while this is being composed would not count as *adding a caption box*. In this study, two instances occurred in which the participants added caption boxes when they were reviewing a set of lesson slides they had created. One pair of participants added a caption box to indicate that time had passed and students had pondered the question posed earlier. This attention to time was absent in their lesson plan. Another instance occurred when a pair of participants added a caption box to show the order of multiple speech bubbles and events presented on the same slide. It may suggest that the participants were aware of the temporality of class events.

The third type of action, *dragging* a caption box, similarly to dragging a speech bubble, refers to users' re-assigning of a caption box they had created in one location (character) to another location (character) on the same slide. There was one instance of dragging a caption box. This caption box was describing a student's unspoken thoughts. The participants first assigned this caption box to a student who simultaneously answered the question. However, when the pair was viewing the slide of the view of students, they decided to have another student involved, thus dragging the caption box with the unspoken thought to this student. This case resembles the one of dragging a student's speech bubble in that both represent students' thinking; after viewing the slide of the view of students, the participants involved more students verbally or nonverbally in class events.

Gestures

The version of *Depict* used in this study contained icons that represented hand-arm gestures. In the template with view of students, student characters had not been given hands or arms. It was expected that if the participants would anticipate instructional meanings conveyed through students' gestures they would add these graphic elements to student characters.

The participants assigned students two types of gestures. In most cases, student gestures were shown as raising a hand when trying to respond to teacher's questions. In other instances, multiple students were assigned writing gestures to illustrate they were working on the assigned tasks. Participants did not use any of the other icons for gestures available in Depict.

In the templates with view of the teacher, the teacher character was given both arms. Participants could have depicted lessons without changing teacher's gestures or locations. However, in this study, the participants added gestures to the teacher in two occasions. These two instances show that the participants closely attended to the teacher's instructional behavior.

In the first case, the participants assigned extra gestures to the virtual teacher[26] to show that the virtual teacher was speaking. Another case happened when the participants added pointing gestures beside the graphs on the board while these gestures were detached from the virtual teacher's body. This addition allows them to demonstrate that the virtual teacher was pointing to the board content while explaining. This addition overcame the graphic constraint that the virtual teacher character was static on the given templates. This instance also shows that when depicting a lesson, the participants were aware of the role of the teacher's gestural interactions with students during instructions

[26] The gestures assigned to show the virtual teacher's speaking may not be shown in the final version of lesson slides due to a programming bug: The objects created from *Inscribe* blocked the gestures.

Table 6.6 Use of Gestures on Characters

Character's gesture	Number of occurrences	Notes
Teacher gesture	4	2 attached to the virtual teacher's body 2 detached from the virtual teacher's body
Student gesture	9	6 raising hand 3 writing
Total	13	

Facial expressions

There are six types of facial expressions available in the version of *Depict* used here. The following table summarizes the number of occurrences of each type of facial expression presented on the teacher or student character in the participants' lesson depiction.

Table 6.7 Use of Facial Expressions on Characters

	Neutral	Neutral speaking	Excited	Uncertain	Bored	Confused /Frustrated	Total
Teacher	0	8	5	0	0	0	13
Student	5	7	2	4	3	2	23
Total	5	15	7	4	3	2	36

Table 6.7 shows that the participants in this study anticipated more student facial expressions than teacher expressions. The participants made use of many of the facial expressions to anticipate students' responses.

In the above section, I discussed the participants' use of graphic features in *Depict*, and their various types of actions with each feature. In the following section, I further examine how visualization of graphic elements on lesson slides plays a key role in enabling the participants to attend to the detail in instructional moves and students' reactions that did not catch their attention in their initial compositions of lesson slides.

Visualization of Lesson Slides

To depict a lesson through lesson slides, the participants needed to utilize different kinds of features and integrate them in *Depict*. As discussed, the participants made use of graphic features and employed them differently to depict their lessons.

While the employment of graphic features differed, visualization of these graphic features played a key role in further prompting the participants to elaborate and revise their lessons. Particularly, the participants, through visualizing partially or wholly completed lesson slides, attended to detail in their instructional moves and students' possible reactions.

In the following table (see Table 6.8), I synthesize the participants' actions, specifically involving changing graphic elements or content in their lesson slides. I also examine the moment in which they made these changes. To do this, I identify two specific phases, *viewing* and *reviewing*, that enabled the participants to refine their lessons.

I define *viewing* as a phase that occurs when users are looking at the slide they are currently composing and have not yet gone to compose the next slide. It may be a semi-composed slide or a slide just completed. In contrast, *reviewing* is defined as a phase taken after they have composed several slides and they then view through that series of slides.

It is important to identify at which phase participants' certain actions on the slides occurred. This identification can show that visualizing slides, including *viewing* and *reviewing*, helps the participants attend to instructional issues they neglected when planning in the text-based format or when composing lesson slides earlier.

Table 6.8 Phases in Which Changes in Lesson Slides Occur

	Template	**Speech bubble**		**Inscribe**	**Caption box**		
	Changing	Editing	Dragging	Editing	Editing	Dragging	Adding
View to change	6	9	3	4	4	1	0
Review to change	0	5	0	0	0	0	2

Among the actions on graphic features discussed earlier, changing templates and editing on speech bubbles, using the *Inscribe* tool and caption boxes are major actions related to making changes in lesson depiction. Additionally, dragging speech bubbles and caption boxes reveal that these graphic objects, initially assigned to one character, could be changed to another character on lesson slides. Finally, adding caption boxes was seen as a modification to lesson slides.

The majority of the actions related to revising lesson slides occurred when the participants were *viewing* the slides. It shows that the visualization of a lesson slide, whether partially or wholly completed, helped the participants to examine and refine the instructional events presented on this format; while planning a lesson in the text-based format cannot afford such opportunity.

Some other actions related to revising lesson slides occurred when the participants were reviewing the slides. First, the actions of adding caption boxes on lesson slides were taken during the participants' review. Additionally, more than half of the editions in speech bubbles were made during the participants' review. Specifically, these editions were all on the teacher's speech bubbles. The participants refined the virtual teacher's verbal instruction, such as providing an explanation of a given table or giving a more specific explanation of a concept, so as to make it more comprehensive to virtual students and help them to accomplish the tasks assigned later on.

The result shows that reviewing a set of composed lesson slides allowed the participants to perceive their lessons as sequential and continuous instructional events that they are able to examine them. Particularly, the participants could manage the consistency of the mathematical tasks in the lesson, and anticipate the teacher's instructional moves and students' possible thinking accordingly.

Conclusion

In this chapter, I examined the use of each graphic feature in *Depict* and identified types of actions on each feature. The different applications of graphic features in lesson slides seemed to indicate the participants' attention to different aspects in instruction.

Regarding the use of templates, the majority usage of teacher-view templates shows that the teacher role dominated the participant's lessons. The use of student-view template indicates the participants' anticipation of students' responses. The presence of board content in slides demonstrates the participants' attention to written inscriptions and presentations of content in their lessons.

Similar to the use of templates, the assignments of speech bubbles to different characters may reveal the users' lesson anticipation involving teacher and student roles. The creating and editing of speech bubbles afford the users opportunity to elaborate the verbal messages communicated in lessons. The dragging of student speech bubble reveals that the participants attended to multiple individual students and intended to involve more students' participation in lessons.

The creation or edition of objects using *Inscribe*, the board writing and drawing tool, allow the participants to generate and examine the appropriateness and the correctness of their presentations. The use of caption boxes allowed the users to describe teacher and students actions or teacher-student interactions. The use of facial expression and gesture features on slides allowed the participants to attend to the teacher's or the students' nonverbal reactions in lessons.

Visualization of graphic features played an important role in allowing the users to reflect and revise their lessons. The users' modifications of graphic elements or content occurred in the *viewing* and *reviewing* phases. It appears to show that *Depict* is a "milieu" (Brousseau, 1997) that the visualization of a single lesson slide or a series of completed slides provides feedback for the users to examine and to detail the moment-to-moment teacher-student interactions. This is a unique feature and support that planning a lesson in text cannot provide.

CHAPTER 7
CONCLUSION

The results of the study provide evidence that *Depict*, a technology tool that allows creating comics-based lesson slideshows to represent interactive aspects of lessons, enables prospective teachers to attend to instructional issues that they had not considered when planning. In the following sections, I present a summary and explanations of the findings, limitations and implications of the study, and suggestions for future research directions.

Revisiting the Research Questions

In this section, I summarize the findings in Chapter 4, 5, and 6 as answers to my research questions.

1. *How do anticipations of classroom interaction about a planned lesson differ when done using a multimedia lesson-depicting environment as compared with talking through the written lesson plan?*

The prospective teachers' lesson planning strategies in the text and verbal conditions share similar traits, which have been identified in the literature. Their lessons consisted of sequences of activities in which the teacher plays a leading role that initiates those activities (Clark & Yinger, 1979, 1987; McCutcheon, 1980). The prospective teachers seemed to fail to consider how they would interact with their students during instruction, in particular how they would orchestrate explanations that attend to student thinking and advance their learning. This lack of consideration of teacher-student interaction has been recognized in novice teachers' lesson planning (Borko & Livingston, 1989; Leinhardt, 1993; Peterson, et al., 1978; Roskos & Neuman, 1995). This lack of consideration of teacher-student interaction when planning can leave novice teachers unprepared to appropriately respond to unexpected questions or answers from students (Livingston & Borko, 1990; Nicol, 1998; Zimmerlin & Nelson, 2000). Attending to student thinking is an important issue that teacher educators and researchers have sought to address (Ball, 1997, 2001; Ball, et al., 2008; Crespo, 2000; Franke & Kazemi, 2001; Kazemi & Franke, 2004). It is important to engage prospective teachers in lesson planning activities that facilitate their attention to student thinking.

When describing lessons verbally, the prospective teachers were better able to anticipate students' involvement than when they wrote written plans. However, they perceived students in a passive role, simply receiving the teacher's instruction. Additionally, the prospective teachers saw students as a collective and did not anticipate individual students' involvement. Anticipating students' possible responses and anticipating how to interact with those responses are important practices in planning and teaching (Ball, 1997; Crespo, 2000; Franke & Kazemi, 2001; Schoenfeld, et al., 2000). This lack of attention to student individuality may prevent prospective teachers from envisioning students' possible thought processes and responses, and consequently prevent them from generating instructional strategies that might respond to students' reactions.

When depicting lessons, the prospective teachers anticipated more teacher and student involvement in their lessons than their counterparts did when describing lessons orally. The prospective teachers who depicted their lesson particularly anticipated that the "teacher" could be a passive role that students interact with. Further, while the prospective teachers in lesson description did not envision any individual student participation, *Depict* participants considered students' individuality in their lessons.

2. *What do prospective teachers attend to in the work of teaching when engaged in depicting a lesson?*
    a. *What do prospective teachers anticipate regarding teacher involvement in a lesson?*

Overall, the prospective teachers specified teacher's instructional moves when depicting lessons. In particular, they composed carefully what the teacher would say, such as the explanations and the presentations of problems that a teacher would need to provide for enhancing student understanding (Borko & Livingston, 1989; Lampert, 2001; Leinhardt, 2001; Livingston & Borko, 1990). They also attended to the representations of concepts and the arrangement of the board content (Lampert, 2001; Leinhardt, 1993; Leinhardt & Steele, 2005). They examined the mathematical appropriateness of instructional examples given in tasks (Mason & Pimm, 1984; Zaslavsky & Zodik, 2007; Zodik & Zaslavsky, 2008). In addition, they specified the teacher's behavior in the classroom (Leinhardt, 1993; Rosebery, 2005).

    b. *What do prospective teachers anticipate regarding student involvement in a lesson?*

The prospective teachers individualized students' participation in lessons. They attributed personality to students so as to anticipate students' possible actions and thinking. They attended to the simultaneity of students' participation in lessons (Doyle, 1986). They became aware of students' non-verbal participation, including gestures, facial expressions and unspoken thoughts (Lemke, 2002). Further, the prospective teachers hypothesized students' thinking and prior knowledge (Ball, 1997; Even & Tirosh, 1995). They also anticipated students' uncertainty or learning difficulties (Lampert, 2001; Schoenfeld, et al., 2000).

c. What do prospective teachers anticipate regarding mathematical work involved in a lesson?

Overall, the activity of depicting lessons allowed the prospective teachers to examine the design of mathematical tasks. Specifically, they attended to the connected nature of adjacent tasks and sought to make connections or consolidate the tasks. They also became aware of the need for decomposing tasks so as to make them manageable and workable. To help students better accomplish the mathematical tasks, the prospective teachers tended to provide resources in different forms. For example, the prospective teachers demonstrated an example of the task so as to make it easier for students to accomplish the task on their own. In another example, the prospective teachers gave an explanation of the given representation (a table) to help students better understand the given information of the task.

3. How do prospective teachers employ the graphic resources to support their lesson depiction?

From the observation of the use of the graphic features and user behaviors in *Depict*, the visualization of lesson slides seems to play an important role in encouraging prospective teachers to discuss and modify their anticipation of interactions with virtual students. By viewing and reviewing, the prospective teachers got feedback and were thus able to examine, elaborate and revise their design of lesson events. It formed feedback loops from a “milieu” (Brousseau, 1997) that affords opportunities for the learning of teaching .

Learning from Interaction with a *Milieu*

In a learning situation, a learner acts on a *milieu* and gets feedback from such *milieu* (Brousseau, 1997). When the prospective teachers started creating lesson slides using *Depict*, they generally viewed the task as being simply to copy what had been written in their lesson plans. However, when *viewing* the partially or wholly completed slides, they became aware of the need to develop more detail in their lessons and attend to moment-to-moment interaction between teacher and students.

Figure 89 illustrates the prospective teachers’ experiences in anticipating lessons using the *Depict* tool. When depicting a lesson, the prospective teachers employed different graphic features available in *Depict*. The feedback was conveyed through their interpretation of graphic representations of class interactions. Through this sequence of action and feedback loops, the prospective teachers were able to examine, reflect and refine their lessons.

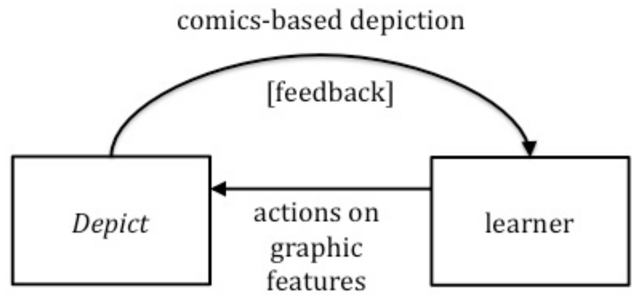


Figure 89. The interaction with *milieu* in *Depict*

For example, in depicting a lesson, the prospective teachers first created a speech bubble on the slide containing a question that the teacher would pose to the class. However, when reading the content of that speech bubble and viewing the slide, the prospective teachers found that they had not yet provided enough context and information to enable students to answer the question. As a result, they modified the question in the speech bubble and proceeded to probe what would happen after.

The results from analyzing the use of graphic features and users' behavior in *Depict* show that the prospective teachers made changes on their lesson slides after *viewing* or *reviewing* them. They attended to instructional issues they had not previously been aware of. They specified what the teacher would say, instead of just describing class activities in general terms. They also attended to students' individual or collective involvement in class activities.

However, as the feedback from depicting a lesson may be influenced by the effect of " the apprenticeship of observation" (Lortie, 1975), the learners may act on the depiction of a lesson based on what they think the teaching should be like. Although the learners can learn to attend to instructional details that they have not had before, they do not necessarily learn exemplary instruction. Due to this, the limitations of the study and suggestions for supporting the interaction with *milieu* will be discussed in later sections.

Graphic Representations as Semiotic Resources Mediating Learning

The study involved a comparison between two groups: Lesson description and Depict. These two groups formed two different activity systems (see Chapter 1) in that the tools involved in the systems were different, thus the outcomes are expected to differ (Engeström, 1993, 1999). The tools in the lesson description activity system available for pairs of prospective teachers included the lesson plans and their language. The tools for *Depict* teachers to anticipate lessons were the lesson plans and the *Depict*.

This study shows that the extent to which the prospective teachers anticipated lesson details, regarding teacher and students roles' involvement in class events, varied in the two groups (see Chapter 4). The results reveal that the prospective teachers using *Depict* anticipated more teacher and student involvement in their lessons. They attended to students' individual or collective active participation; while the teachers in the lesson description condition were more likely to view students collectively as passive participants.

This finding suggests that the graphic resources in *Depict* play a key role in facilitating the prospective teachers' anticipating teacher-students interactions in lessons. These graphic features encouraged the prospective teachers to create, review and revise their representations of lessons. Hence, the comics can be seen as semiotic resources (Herbst, et al., 2011) that mediate the pairs of prospective teachers' discussion about the ways of virtually enacting their lessons. The comics-based semiotic resources mediate the teachers' generation of teacher-student moment-to-moment class interactions.

Approximations of Practice in Depicting Lessons

Approximations of practice provide novices with opportunities to practice their professional work in settings with different degrees of authenticity (Grossman, et al., 2009). The activity of planning a lesson may be considered as a less authentic approximation of practice if teachers only select learning activities and determine topics to be covered. It does not require one to fully participate in the context of interacting with a class of students. However, the activity of anticipating a lesson in *Depict* affords the prospective teachers the opportunities to virtually enact their lesson and engage in simulated instruction.

Indeed, this study shows that the lesson plans generated in text or verbally included mathematical tasks that were impractical to implement and lacked detail regarding interactions with students (Leinhardt, 1993). These lessons did not illustrate the "nature of classroom activity", and they were "simply a collection of sequentially described actions by teachers and students" (Leinhardt & Steele, 2005, p. 99). On the other hand, the prospective teachers who used the *Depict* tool to create comics-based lesson slideshows immersed themselves in the classroom setting and demonstrated their capacity to incorporate detailed instructional actions by the teacher, student reactions, and mathematical tasks in their lessons. The prospective teachers unpacked their planned discrete class activities and attended to their relational nature among teacher, students, and mathematics (Cohen, 2011; Cohen, et al., 2003; Lampert, 2010). The activity of depicting lessons affords the novices opportunities to approximate the interactive nature of teaching practice by accessing and practicing "elements of interactive teaching in settings of reduced complexity" (Grossman & McDonald, 2008, p. 190).

Depict should not be seen as merely a lesson planning software tool. Creating comics-based lesson slideshows is a contextualized learning environment (Rosebery, 2005). For example, when depicting a lesson, the prospective teachers enriched the substance of the instructional dialogues for the purpose of advancing students' learning. In particular, the prospective teachers elaborated the presentations and explanations of the mathematics problems posed to students, so as to help students better understand the questions. The activity of preparing appropriate presentations and comprehensive explanations prior to teaching practice has been identified in expert teachers' lesson planning or lesson agendas (Borko & Livingston, 1989; Lampert, 2001; Leinhardt & Steele, 2005). *Depict* provides a tool for prospective teachers to approximate this aspect of teaching practice.

Depict invited the prospective teachers to generate examples that they intended to employ in their lessons, and examine the "correctness" (Zodik & Zaslavsky, 2008) of these examples. While useful examples are crucial in supporting the learning and exploration of mathematics concepts, choosing appropriate examples is challenging and requires special kinds of teacher knowledge (Hiebert, et al., 1997; Leinhardt, 2001; Leinhardt & Steele, 2005; Zaslavsky, 2010). *Depict* provides a context for prospective teachers to formulate instructional examples, thus potentially developing their knowledge for teaching.

The comics-based environment is not photorealistic. However, the ways in which *Depict* engaged prospective teachers in approximating the teaching practice can be considered a type of "pedagogy of enactment"(Grossman & McDonald, 2008; Kazemi & Hubbard, 2008). It engages prospective teachers in experiences that "simulate the sorts of situations teachers confront in the midst of instructional practice and thus engage teachers in the ways of knowing involved in classroom teaching" (Kazemi & Hubbard, 2008, p. 438), and it demonstrates its high degree of authenticity in relation to practice (Grossman, et al., 2009).

Limitations

Limitations of *Depict*

While *Depict* is a "milieu" (Brousseau, 1997) that allows prospective teachers interact with graphic features and thus generate learning, the quality of the feedback that users get from the "milieu" may be tainted by the effect of " the apprenticeship of observation" (Lortie, 1975). The users/learners may depict a lesson based on what they think the teaching should be like. In this way, the learners can attend to details of instruction that they have not been aware of and thus learn the work of teaching. But the learners do not necessarily learn instruction that is exemplary according to any specific criterion.

In the analysis done for this study, several instances were found that the participants did not have competent knowledge in mathematics and did not have good understanding of students' knowledge. The lack of sufficient mathematics knowledge for teaching resulted in an improper and impractical design of teacher-student interactions. Hence, it would be helpful to provide learners with immediate and timely resources and feedback to compensate for these shortcomings. External resources, such as textbooks and student work artifacts, can help prospective teachers to identify students' prior knowledge and ways of thinking or common misconceptions. Therefore, future research is needed to investigate the ways in which a virtual setting with various types of resources enables teachers to develop practice-based knowledge for teaching.

Limitations of the study

A limitation to this study concerns the size of the sample. A future study should be conducted with a larger sample of prospective teachers. While this study's detailed examination of prospective teachers' depicted lessons and verbal descriptions of lessons helped to explore the quality and nature of these two types of activities, it is needed to investigate the work of lesson anticipation produced by a larger sample of prospective teachers, in order to make more valid claims.

Despite this limitation, this study explored the affordances of using graphic resources in *Depict* to attend to instructional details. The study found that the prospective teachers attended to instructional moves, mathematical tasks and student thinking when using the tool. The findings provide a rich description of the language used during the activity of depicting a lesson, thus generating a list of advantages of using *Depict*. This study also identified different characteristics of lesson anticipation when done with two different mediation tools (verbal description and *Depict*). Future research conducted with a larger number of prospective teachers could be helpful in discovering more characteristics of lesson anticipation using the *Depict* tool and could provide further grounds to conceptualize the activity of depicting a lesson. This would be helpful in developing a checklist or a rubric for assessing teachers' lesson planning and anticipation.

Another limitation to this study is that the participants were not asked to revise their written lesson plans after they had anticipated their lessons using *Depict*. A future study could be conducted with a follow-up lesson plan revision after users anticipate lessons in *Depict*. In this way, it can be examined whether and in what ways prospective teachers' learning about instruction has attained.

One other limitation of the study is the limited use of *Depict*: the participants only used the *Depict* tool once. Systematic incorporation of the *Depict* tool into activities in a teacher preparation program should be considered and studied. In this way, the development of teacher knowledge could be tracked and investigated, and the impact of learner-generated representations of teaching in teacher learning could be examined. It would be useful to determine in what ways the *Depict* tool supports the development of teacher knowledge and what specific aspect of knowledge is enhanced. It would be also useful to examine whether and how the learning experience in *Depict* impacts prospective teachers' actual teaching practice.

Future applications of the *Depict* tool in teacher preparation settings are suggested as follows: The lesson slides created from *Depict* could serve as records of a prospective teacher's practice in learning teaching. These representations could become references for future enactment of lesson activities. In addition, these artifacts could be seen as "common media", like videotaped or animated representations of teaching, to elicit discussion about teaching and learning among peers or with teacher educators (Herbst, et al., 2011; van Es & Sherin, 2002) and hence promote insights into the complexity of teaching. Furthermore, the ways in which prospective teachers create *Depict* lesson slides can serve as an indicator of the degree of their attention and sensitivity about instructional issues. These representations can be used for evaluating teacher learning.

Implications for Practice

The study's findings have implications for teacher education. The study suggests that lesson planning is a contextualized learning experience. Instead of imagining "what" to do in a lesson (Casey, 2000), teachers should be engaged in experiences that help them imagine "how" the events of lessons would unfold. While learning to plan a lesson is a common activity that prospective teachers do during their teacher preparation programs and scaffolding tools have been provided to engage prospective teachers in developing thorough lesson plans, the study suggests a comics-based virtual environment for prospective teachers to immerse themselves in the "imagined classroom" (Rosebery, 2005) as the teacher role in the classroom setting. By anticipating moment-to-moment teacher-students interactions, this tool enables prospective teachers to simultaneously attend to teacher moves, students and mathematics, the essential elements in instruction.

The findings also imply that in order to engage prospective teachers in learning about and to do the work of teaching, teacher educators should consider directing prospective teachers' attention to issues of temporality, multimodality and multivocality in instruction (Herbst, et al., 2011). The study reveals that the prospective teachers attended to issues of temporality, multimodality and multivocality in instruction when using *Depict*. In *Depict*, the prospective teachers viewed and reviewed lesson slides. This allows them attend to temporal aspect in teaching-- examine, arrange and modify the temporal order of instructional events. The awareness of temporality seems to help the prospective teachers to examine and refine mathematical tasks in their lessons.

Another important characteristic of anticipating lessons using *Depict* is allowing prospective teachers to attend to student involvement. By creating board content and viewing templates of classroom, the prospective teachers attended to multimodal communication with students regarding mathematics content. Further, the prospective teachers attended to multiple students' diverse responses in their lesson anticipation.

In particular, students were seen as individual active participants. Individualizing students can help the prospective teachers further attend to students' thinking. There have been great efforts in developing teachers' ability to attend to student thinking (Crespo, 2000; Franke & Kazemi, 2001; Kazemi & Franke, 2004). For example, a lesson planning tool, *Thinking Through a Lesson Protocol* (TTLP), is proposed to guide teachers focusing on students' mathematical thinking and implementing mathematical tasks while planning lessons (Smith, et al., 2008). The activity of depicting a lesson provides an alternative approach to develop novices' knowledge about student thinking in relation to mathematical tasks.

The study's findings also suggest that prospective teachers may benefit from generating comics-based representations of teaching on their own. Different forms of representations of teaching have been extensively employed in teacher education settings. The ways in which these representations of teaching are utilized differ. However, learners of teaching are generally considered to be consumers or observers of these artifacts (Crespo, et al., 2011). This study provided opportunities for novice teachers to generate their own representations of teaching. This activity allowed them to anticipate what their teaching might look like, examine the lesson events, and simultaneously attend to instructional detail that they have not been aware of.

A possible follow up to this study could compare depiction with other lesson anticipation activities that did not involve depiction: Might they also facilitate prospective teachers' learning to attend to temporality, multimodality and multivocality in instruction. For example, teacher educators could ask prospective teachers to create classroom dialogues to anticipate how their lesson would unfold. These dialogues could be contrasted with uses of the *Depict* tool. They could be useful for understanding novices' learning about instruction and teaching with different resources. Specifically, it would be helpful to detect whether learner-generated comics-based representations of teaching play a unique role in prospective teachers' learning to teach.

Implications for Research

This study suggests that comics-based representations of teaching could be semiotic resources that mediate prospective teachers' learning about instruction. There have been extensive studies and discussions about semiotic resources employed in classroom learning. For example, the use of discourse, gestures, signs and symbols play important roles in facilitating students' mathematics and science learning (Arzarello, et al., 2009; Lemke, 2002; Roth & Lawless, 2002). However, the use of semiotic resources in teacher learning has not been fully discussed and explored, especially comics-based resources. Therefore, further studies could investigate the ways in which graphic resources facilitate prospective teachers' learning to teach.

The analysis of *Depict* users' generating class events via graphic representations is a methodological contribution of the study, showing how to transcribe depicting actions in software tool into text and then how to analyze such transcriptions using linguistic tools. As a result of transcription and analysis, I was able to determine the class events anticipated through graphic representations. This method helped me to compare the class events generated through other activities (i.e. written lesson plan, verbal lesson description). This transcription is necessary and crucial because it allows identifying the ways in which teachers anticipate their lessons and comparing them. It would be helpful to develop a thorough transcription system to transcode the depicting actions on *Depict* using Systemic Functional Linguistics (SFL) terms.

APPENDICES

Appendix A
Students' Mathematical Conceptions

Patricio Herbst

Students don't come to us as empty slates. They know things. And they use what they know to handle the problems we give them. They do that even when their answer is not the one we wish they gave—students' errors can often be explained in terms of what they know rather than in terms of what they don't know.

For example, when a 5th grader writes that $7 – 9 = 2$, one can explain what they were thinking by realizing that earlier in life, when the student started doing subtractions, he learned to subtract the smaller from the larger. It is likely that the student thought about that problem as $9 – 7$.

To teach secondary mathematics we need to be aware of what students already know. This is important because we will be posing problems to them and expecting them to use their knowledge to make sense of those problems. It is also important because they will be answering those problems, often erroneously. These errors show evidence of the ways that students are connecting new experiences with old knowledge, not deficiency or ill will on their part.

As teachers we need to learn to embrace student errors. We need to work with students' errors. When teaching a new concept in high school, it is unlikely that the concept will have no relationships with concepts students knew from before. For example, subtraction among integers is related to subtraction among whole numbers in that both of them "undo" addition or that both of them can be represented as moving to the left in the number line. We will be helping both our students and ourselves if we take old knowledge into account when we teach new knowledge.

But new ideas will be somewhat different than the prior knowledge. For example, subtraction among integers can hardly be thought of as "take away," without having to complicate the metaphor. (You could use "take away" by thinking about going into debt when you take away more than you had, but the interpretation gets increasingly strained for calculations like -9 -7:"If I am missing 9 stuffed animals and my sister steals 7 from me, how many stuffed animals will I be missing?"). Since new ideas will be different from what students already know, as teachers we will not only have to work with those existing ideas but also against them.

Our job is to create conditions for students to question what they know and make it evolve into something new. In secondary mathematics, ideas get much more complicated than subtraction, so it is important for you to investigate deeply what students may know that can assist them in learning new ideas and that can prompt them to make errors.

In the above analysis of subtraction, we used three "conceptions" of subtraction to make sense of what may be happening when you bring students from subtraction among whole numbers to subtraction among integers. Those conceptions were:

- Subtraction is taking away
- Subtraction is moving to the left on the number line
- Subtraction is undoing addition

Mathematically, you know that the third one (undoing addition) is the most general one. But for teaching, you need to know all of them, since all of them are useful at different times. (For example, "take away" is great to make up problems for young children.). The rest of this document will illustrate for you the conceptions students have of one of the most important ideas in schooling: the idea of linearity and, especially, students' conceptions of slope.

Conceptions of slope

Consider first the following overview. It provides four conceptions of linear function, that we could call (going around, counterclockwise) "table," "proportion," "equation," and "graph." The figure presents them in abstract language to appeal to your mathematical taste, and makes the point that all of them are mathematically correct. They can be useful at different times and they can bring up different kinds of errors.

That when displayed in tables such as

X	Y
x_1	y_1
x_2	y_2
x_3	y_3
x_4	y_4

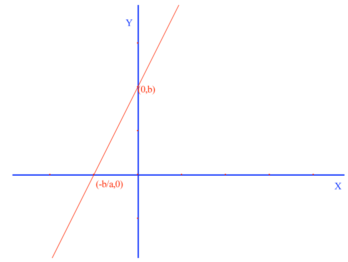
have that

$$\frac{y_4 - y_3}{y_2 - y_1} = \frac{x_4 - x_3}{x_2 - x_1}$$

for any two associated pairs of values x→y

Linear functions are particular kinds of correspondences between two numerical magnitudes X and Y

That when graphed on a Cartesian coordinate system fall on a Euclidean line



whose slope (tangent of the angle with the horizontal axis) equals the constant ratio $\frac{y_2 - y_1}{x_2 - x_1}$

That vary proportionally (pending possibly a change of origin), namely $Y-Y_0=k*(X-X_0)$.

That can be expressed as the set [(x,y), $x \in X$ and $y \in Y$, such that $y = m \cdot x + b$] where *m* and *b* are constants.

In friendlier (but less exact) terms you could express those conceptions as follows

- A linear function is a table where the quantities vary at the same rate
- A linear function is a proportion between two quantities
- A linear function is a formula that says what to do to one quantity to get the other
- A linear function is a straight line

Each of those conceptions brings with it a conception of **slope**.

- Slope is the rate of change of the quantities in a table
- Slope is the scale factor of the proportion
- Slope is the factor one multiplies the independent variable by
- Slope is the tangent of the angle that the line makes with the X-axis (or a measure of the steepness of the line)

Let's see them with examples and also anticipate some errors.

<u>Table</u>

Operations:

1. Subtract to find difference between y-values and between corresponding x-values, then compare differences to see if the rate is constant, or use the difference to "work up" to the desired value by repeated addition or multiplication according to the number of increases in x.
2. Subtract to find the differences between a pair of y values and the corresponding pair of x values. Compare those two differences by creating a ratio in simplest form. Choose different pairs and form their ratios to see if the rate is constant, or use the ratios to find a missing value.

Consider the linear function given by the following table

X	Y
1	4
2	7
3	10
4	13

What is the slope? Easy, for each unit change in the X the Y changes by 3, so the slope is 3.

Students start having experiences with these kind of linear patterns early in elementary school. They actually see problems that look more like the following

Continue the pattern past 20: 4, 7, 10, 13, …

In these exercises it is tacit that the number you must give next in the pattern is the one that corresponds to the next (1 more) after the number you wrote before: the tacit independent variable is the set of whole numbers. This is apparent in problems like

Complete the missing numbers in the pattern:

4	7			16		22

Now consider the following tables:

X	Y
3	5
5	11
7	17
9	23
10	

In the table on the left, What do you think students might say if you ask them what the slope is? What might they write for the y-value in the last row?

In the table on the right, what do you think students might say if you ask them to do two more rows of the pattern?

X	Y
3	7
5	11
10	21

To find the slope in a table one would need to find how the changes in Y and the changes in X vary together. In the table on the left, that since a change in 2 in the x variable (5 – 3 = 2) corresponds to a change in 6 in the y-variable (11 – 5 = 6), then a change in 1 (10-9=1) which is half of 2, should correspond to a change in 3, which is half of 6, thus the corresponding value for 10 is 26. Likewise in the table on the right since a change of 5 corresponds a change of 10, and to a change of 2 corresponds a change of 4, then to a change of 7 (to X=17) would correspond a change of 14, (Y=35) and to a change of 3 (to X=13) would correspond a change of 6. A common error students make is to continue the pattern in the Y-variable without using the X-value to control it.

Proportion

Operations: Cross multiply; algebraic manipulations, multiplication, division; find ratios of quantities; comparison; multiplying a quantity by a constant rate of change

Consider the following situations:

- Fast-walkers burn calories rapidly during the first five minutes (the "ramp-up" stage) and then continue to burn calories at a steady (but lower) rate thereafter. If I fast-walk 15 minutes, I burn 45 calories during the first 5 minutes and 100 calories in total. How many calories would I burn if I fast-walk 30 minutes?

- Joe the Handy Man charged clients a flat "house call" charge plus a fixed hourly rate. Last month we paid $65 for a one hour job, and this week we paid $95 for a 1.5 hour job. How much would Joe charge for a 2.5 hour job? How much for a half hour job?

- A cell phone carrier has a rate plan that gives 800 minutes for $60/month, and another rate plan that gives 2000 minutes for $100/month. How much should I expect to pay for a plan that gives me 500 minutes?

Students have done problems of "this sort" since they started learning about multiplication. The problems sound like "proportion-type" problems, and with some extra considerations (e.g., calories spent in ramp-up time, fixed cost of house call, fixed cost for a phone line) they do have a proportion inside them.

A student might solve the first problem, for example, by reasoning as follows:

In the 15 minute walk, after the ramp-up I burn 55 calories in 10 minutes. In the 30 minute walk, after the ramp-up I walk for 25 minutes, so I need to solve the proportion

$$\frac{55}{10} = \frac{x}{25}$$

I can solve this by cross-multiplying:

$$55 \cdot 25 = x \cdot 10$$

and then solve for x by dividing by 10: x = 137.5. This is how many calories I burn after the initial ramp-up period, so the total I burn is 182.5 calories.

Although the procedure one would follow for the other two examples would not be exactly the same as in the first, they can also be solved by proportional reasoning. What would those solutions look like? How would they be different from one another? What kinds of mistakes would a student be likely to make, and why?

<u>Formula</u>
Operations: Use algebraic manipulations to put equations into slope-intercept form; substitute values for x and/or y, b, m in order to find other values.

Consider the following expressions

Y – 3X = 5	Y – 5 = 3X
2X + 3Y = 5	$\frac{X-3}{Y}=2$

What is the slope in each of them? What do you think students might answer?

<u>Graph</u>
Operations: Locate points; "up and over," "rise over run," or change in y over change in x for slope; eye the graph for steepness and direction; visualize and quantify shifts in the plane (e.g., seeing a line as being a translation along the y-axis of a line through the origin)

Consider the following problems

- Suppose that you drew the line through points (15, 48) and (30, 96), what is the slope of that line?
- A line of slope 3 passes through (31, 96), does it also pass through (15, 48)?
- Suppose that you drew the line through points (15, 48) and (31, 96), what would be the y-value for x = 62?

How do you think students might do those problems? What kinds of errors could you expect students to make?

A concluding thought
When students solve problems they reach to anything they know to produce an answer. Likewise when they learn from their teacher, they connect new ideas to the old ones they know. It is natural that within that sense making activity, some errors will appear. By knowing what students' conceptions are and what errors they might make, we will be better prepared to understand what they are thinking and to plan how to teach them.

Appendix B
Guiding Questions for Annotating Student Work

Some questions to focus your annotations (you need not answer all of these questions, they are given to orient you on what you might comment)

- Does the student's work include evidence that they were thinking about *slope*? What is that evidence?
- Does the student's work include evidence that they were thinking about *linear functions*? What is that evidence?
- If they were not thinking about *slope* or *linear functions*, what else might they have been thinking about? Is it reasonable for them to have thought about that?
- What might the student have been thinking that is not explicitly written? What is your evidence for this?
- What, if anything, is missing from the student's answer?
- What terminology does the student use? Is it used correctly? If not, how is it being used?
- What notation does the student use? Is it used correctly? If not, how is it used?
- What representations of "linear function" does the student use? Are they used correctly? How are they used?
- What further questions would you ask if you met the student?

About mathematics literacy:

Does the work include verbal content? If so, is it written in full sentences? Is it coherent?

Comment about the student's use of logical connectors and other words that are important mathematically (e.g., so, such as, if/then, therefore, either/or, because, and, only if, etc.)

Comment about the student's use of symbolic statements—are they well written or are they ambiguous? For example, sentences that involve symbols like =, sentences that include product of quantities, etc.

Comment about the student's use of tables—are they completed well? Are they reliable to read off information? Does the student read the tables well?

Comment about the student's use of graphs and other pictorial representations. What assumptions do they make? Are conventions about the use of graphs respected?

How is the work organized on the page? Is the "reading order" clear? Are the important elements of the student's thinking written prominently on the page?

If you were the student's teacher, what (if anything) would you suggest be modified about the way the student communicates in writing

Appendix C
Lesson Plan Worksheets

Teachers' Names:

Course:

Lesson: Explanation of slope

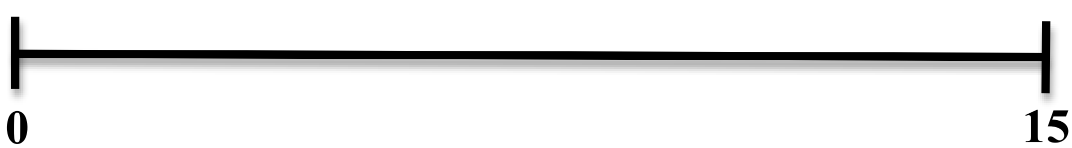
FYI: Relevant goals, from the MI Curriculum Framework
As students mature from the middle school on, they develop a solid understanding of both linearity and proportionality. Students should

- Explore and describe visual and numeric patterns, including linear expressions and patterns
- Explore patterns (graphic, numeric, etc.) characteristic of families of functions
- Connect an initial state to a final state and generalize a rule that describes a pattern of change.
- Develop a mathematical concept of function and recognize that functions display characteristic patterns of change (e.g., linear, quadratic, exponential).

Tonight you are going to plan a **15-minute explanation of slope** to your class placement (or, if not applicable, to a regular algebra I class). At this point in your development as teacher, we will understand a "plan" to be a timeline or a list of segments you make in a lesson (that is, indicating what is going to happen and when). (There is, of course, much more to planning than this — but for tonight we are going to focus on this facet only.)

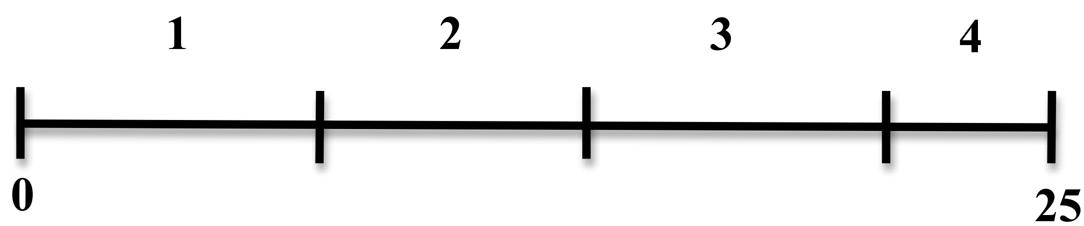
Your job has two parts. First, produce a timeline of your lesson, showing the order and duration of each segment. Second, describe each of those segments. The rubric on "explaining concepts" can help you figure out what to do.

Use the following timeline to insert the intermediate points that define the segments in your explanation. Then describe those segments in the following pages. (The back shows an example timeline for another lesson.)



Example: Lesson on polygons

Explanation of the formula for the number of diagonals of a polygon



1: Probe knowledge of “diagonal.” Pose “big” problem—how many diagonals in a polygon of 12 vertices? Hear some estimates. (1 min) Ask: wouldn’t it be nice to predict the number without having to draw and count? Let’s figure out if there is a pattern. Ask about a quadrilateral, a pentagon, hexagon, etc. (8 min)

2: Draw a table and put there the results they found. Ask if they see a pattern. Ask them to predict the value for 12. Add the column: diagonals through one vertex; complete table with class. Ask if they see a pattern. Ask them to predict the value for 14. (6 min)

3: Ask if they could predict a value without having to fill the whole table, say for 85 sides. Prompt for formula. Write formula and describe what each factor means. Explain why you divide by 2, common error. (7 min)

4: Give possible problems they will have to do. (4 min)

Segment #_____

In your description, please include:

- What is the mathematics that will be done?
- What will the teacher be doing?
- What will students be doing?
- How long might it take?

Checklist—in this segment we are…	√
Problematizing the concept	
Connecting to prior knowledge	
Representing the concept	
Exemplifying the concept	
Identifying core principles of the concept	
Identifying key errors	
Establishing the boundaries of the concept	
Assessing and holding students accountable	

Description of segment:

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