BIOLOGY TEACHERS' INSTRUCTIONAL EXPERIENCES WITH INQUIRY-BASED CURRICULUM MATERIALS FEATURING 3-D COMPUTER ANIMATIONS

by

KYUNG-A KWON

(Under the Direction of J. Steve Oliver)

ABSTRACT

The purpose of this research was to examine science teachers' instructional experiences when using *Clinical Clark,* a new curricular module based on 3-D computer animations of biological processes, which was developed by a UGA research team. Six participant teachers' instructional activities were observed in their natural teaching environment as the teachers planned for, taught, and reflected on a series of lessons that use the 3-D animation curriculum materials.

This study identified the factors teachers considered when planning to teach using the 3-D animation materials. The teachers had many previous and common experiences when teaching students the concept of osmosis. Furthermore, the teachers shared many of their views on the benefits of using technology-based curriculum materials. In the planning process, the teachers' views about how science teaching should be conducted were the strongest factor in their decisions about selection of curricular materials. The teachers considered a variety of information about students in planning the use of the curriculum materials. Students' engagement also influenced the teachers' decisions about choosing new curriculum materials.

This study documented how the teachers enact the science instruction in their classes. The findings of the study show that all teachers offloaded responsibility onto the curriculum materials to some extent. Findings showed that this occurred because they had confidence in the content of the material as an inquiry activity including a real life example, and because they were certain that the materials would improve their students' knowledge. According to the nature of the teachers' overall relationship with the curriculum materials observed in the class session, I have categorized their implementation along a continuum and classified the teachers' offloading as *Full offloading, Modest offloading, and Minimal offloading* in order to describe the degree to which the teachers offloaded the material. Finally, implications of curriculum use for science curriculum developers, science teacher educators, and science teachers are discussed.

INDEX WORDS: Science teacher, Technology-based curriculum material, 3-D animation, Relationship between teacher and curriculum material, Implementing a new curriculum material, Offloading, Case study

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CHAPTER 1

INTRODUCTION

Technological progress has penetrated all fields of human life with a major impact on society and knowledge. People who live in industrialized countries are witnessing increasingly rapid and revolutionary changes and adapting to them. Many of these technological advances have found their way into our schools and our classrooms where technology is being used. These include digital projectors, document cameras and electronic whiteboards, as well as netbook computers, and educational software.

Over one hundred years ago Thomas Edison (1913) predicted a revolution in education.

> "Books will soon be obsolete in the schools. Scholars will soon be instructed through the eye. It is possible to teach every branch of human knowledge with the motion picture. Our school system will be completely changed in ten years." (Seattler, 1968, p.98)

Edison was a good anticipator but also over-predicted. Textbooks still exist in the classroom today. Nonetheless, no one could deny that technology has great potential for shaping instruction. Classrooms have, indeed, changed greatly over the years as new technologies have become vailable. For instance, through the last century various technologies such as the overhead projector, 16mm film projector, television, and more recently computers and PDAs have been introduced in the K-12 classroom. According to the National Center for Educational Statistics (2010) report, in the year of 2009, 97 percent of teachers had one or more computers located in the classroom every day and Internet access was available for 93 percent of the computers located in the classroom every day and for 96 percent of the computers that could be brought into the classroom.

Teachers in today's classrooms are experiencing students who are "digital natives." These students have grown up in a technology-rich environment that includes greater access to multimedia content and the widespread availability of mobile computing devices that can access the Internet, social networking, and digital games. These students often are more proficient in the use of technology than are their teachers. These students also have no understanding of why technology would not be used in the classroom. Because the use of technology is becoming more pervasive, we need to prepare to use technology for our students in ways that connect to their lives.

In recent years, school subjects have experienced widespread curriculum revision and new curriculum development. To some extent, every technological innovation presents an opportunity to rethink and reimagine a curriculum. (Dillon & Jobst, 2005; Gustafson, 2002; McKenney, 2008; van Merriënboer & Martens, 2002; Moreno, 2005, 2006; Rieber, 2005). In particular, emerging technologies, such as computers and the Internet have attracted many people to research and practice focused on improving education with technology. Even chalkboards were once a novelty. Evans (1910) described the chalkboards' effective use and pointed out the pedagogical possibilities—"the teacher could use the blackboard to motivate students and to assist them in organizing information" (p.101).

Each new technology such as computers, devices that can be attached to computers (e.g., LCD projectors, interactive whiteboards, digital cameras), networks (e.g., Internet, local networks), and computer software opens new potential for supporting teachers' abilities to teach toward the aims of each school subject. For science, professional organizations that have an impact on science education at the national level in the US regard the matter of technology use as an important component in the science classroom. The National Science Education Standards (NSES), for instance, encourages teachers to apply “a variety of technologies, such as hand tools, measuring instruments, and calculators [as] an integral component of scientific investigations” to support student inquiry (NRC, 1996, p.175). These science education groups and the reform documents they have generated provide a rationale for science teachers to integrate technology and inquiry-based teaching into their instruction in order to better prepare students for the science and technology of the 21st century (American Association for the Advancement of Science, 1993; National Research Council [NRC], 1996, 2000).

For educational technology tools, researchers describe activities and projects that can be used to facilitate learning. They also describe the learning process, the role of the student, the role of the teacher, and ways to assess the learning process. For science, Novak and Krajcik (2006) suggest that utilizing technology tools in inquiry-based science classrooms allows students to work as scientists. They provide examples of various learning technologies (microcomputer-based laboratories, modeling software, the Web and digital libraries, digital cameras, hypermedia construction tools, applications for hand-helds and visualization tools) and how they aid learners in developing understanding. Belland, Glazewski, and Richardson (2008) examined computer-based programs for middle school students to use while trying to solve real world authentic problems. They reported that problem-based learning in middle school science classrooms enhanced learning through the addition of different types of scaffolds.

Building on the benefits of technology integration in the classroom and in an effort to support inquiry-based science activities for high school students, a team at the University of Georgia developed curriculum materials based in 3-D animation funded by the National

Institutes of Health (NIH). The project team, within a collaboration that includes veterinary scientists, science educators, biologists, dramatic media experts, gaming experts, and high school teachers, concentrated their efforts on developing and refining a set of inquiry curriculum materials based on high quality 3-D animations of anatomical and physiological processes in animals. The 3-D animation curriculum materials are packaged as a complete unit which includes student activity software and structured teachers' guides.

For the past two years I have had an opportunity to participate in the project, and my interest in the use of the curriculum materials in classroom has grown along with the development of the curriculum materials. Like other researchers, I recognize the benefits of applying technology, but my focus is on how teachers use the technology- based curriculum material in the classroom. During that time, several questions have occurred to me: What characteristics of technology cause a teacher to want to use it in their instruction? What factors determine whether a teacher believes that a technology is leading to greater learning by their students? How do secondary school teachers harness this technology to produce better quality instruction?

Nevertheless, despite increases in subject-specific software and research supporting the use of educational technology in the classroom (e.g., Epper & Bates, 2001; Laborde, 2001; Passey, 2000), teachers still seldom teach with technology. Diem (2000) claimed that technology has not been used effectively in the classroom. He stated that it is easy to deliver technologies to the classroom, but helping teachers to be comfortable implementing new instructional methods aimed at active student learning is far more difficult.

Researchers who have attempted to untangle the complex ways that teachers interact with these materials have focused on factors that influence the use of the material, such as teachers' characteristics and factors in the instructional context, as well as the ways in which teachers draw from the materials to design instruction (Remillard, 2009). While this research has contributed a great deal to our understanding of factors that influence teachers' use of curriculum materials, it has largely left unanswered questions about how the characteristics of these innovative materials ultimately influence teachers' instructional practice, including their use of curriculum materials. In particular, teachers' implementation of technology-based curriculum material has received little attention.

Approach to the Study

The research stemmed from my awareness of the teachers' role as the main initiator or decision-maker who chooses and selects curriculum materials that their students are going to use as an inquiry activity. I believe that teaching is deliberate and planned. For example, teachers may decide to give one assignment to all students from a single textbook or to give multiple assignments to all students from a variety of sources. A decision may also be made to use multiple objectives or to select learning materials to fit the instructional needs of various individuals or groups in the class. Teachers may choose from among a wide variety of options concerning how they will proceed.

One of a teacher's main roles is that of designer and implementer of instruction (Clandinin & Connelly, 1992; Combleth, 1988; Snyder, Bolin, & Zumwalt, 1992; Brown, 2009; Remillard, 1999, 2005). Teachers at every level prepare plans that assist the organization and delivery of their daily lessons. These plans can vary widely in their style and degree of specificity. Some instructors prefer to construct elaborately detailed and typed outlines; others rely on the briefest of notes handwritten on scratchpads or notebooks. Regardless of the format, all teachers make decisions about the strategies and methods they will employ to help students move systematically toward learner goals.

Over the years, researchers have acknowledged the powerful influence that teachers have on the curriculum implementation process. In general, teachers do not implement the curriculum in their classrooms in the same way even in teaching the same curriculum material. Clark and Elmore (1981) reported that teachers adapt curricula to fit their knowledge, priorities, and unique classroom settings while Brophy and Good (1974) found that teachers influence curriculum implementation by deciding which topics and activities are appropriate for their students. Doyle and Ponder (1977) reported that the likelihood of successful curriculum implementation depends largely on teacher judgments regarding the magnitude of change required for implementation. Although there are limited research findings available in this area, the studies referred to above suggest that the teacher plays a critical role in the curriculum implementation process.

One of the central issues of my research interest centers on whether teachers will find the 3-D animation curriculum materials to be instructionally robust so that they can be implemented with a wide range of student groups across several different classes. A fundamental assumption of this work was that the enactment of the curriculum materials relies on teachers to implement them for the specific students being taught in that specific class. For this study, my research focused on the views and practices of science teachers in teaching units or individual lessons with the 3-D animation materials.

I broadly build on the research on teacher thought processes that has been done by Clark and Peterson (1986) and Shavelson and Stern (1981). Clark and Peterson (1986) outlined a model of teacher thought and action. This model shows how different parts of the research on teachers' thinking relate to one another. In an extensive review of research on teacher thinking, Shavelson and Stern (1981) constructed a schema of teachers' thought processes. Their work has been used by educational theorists, researchers, policymakers, curriculum designers, teacher educators, and teachers themselves over the past twenty years (Artzt & Armour-Thomas, 2002; Darling-Hammond, 1998; Moreno, 2004, Tharp & Gallimore, 1991). Among the components of teachers' thought that seem to impact instructional practices are planning prior to instruction (Clark & Elmore, 1981), monitoring and regulating during instruction (Clark & Peterson, 1981; Forgarty et al., 1983), and assessing and reflecting after instruction (Ross, 1989; Simmons et al., 1989).

In this study, I use the Teacher-Curriculum Relationship Framework developed by Remillard (2005). There are four major constructs in the framework: the teacher, the resource, the participatory relationship, and the planned and enacted curriculum. The emphasis on the relationships among these four constructs "allows the framework to represent the cycles of design before, during, and after classroom practice" (Remillard, 2005, p. 236). She proposed using this framework as a lens for studies of teachers' interactions with the curriculum. Beside Remillard's framework, I also used Brown's (2009) curriculum enactment framework to investigate how teachers use curriculum materials. He proposed his framework as a non-evaluative tool for studying how teachers use materials and how designers can create materials that influence teaching practice. Those two frameworks will be discussed in detail in later chapters.

Based on these two frameworks, I examined what teachers take into account when selecting classroom tasks for their students, what teachers consider as they plan their classes, what references they use, what elements and aspects they keep in mind, and how they make decisions as to what is most important to them. This research reflected the evolving circumstances that result from recent education reforms. The research on teachers' thoughts, decisions, and behaviors concerning the new curriculum is expected to help to construct a better portrayal of teacher and curriculum material, especially based on technology.

Purpose of the Study

The purpose of this study is to examine teachers' instruction-related experiences when using new inquiry-based curriculum materials that include 3-D models and animations. The study is designed to contribute to the knowledge base related to interpreting teacher decision making in the curriculum implementation process in science classrooms. This study focuses on six teachers' teaching activities related to using new materials: (1) instructional planning prior to instruction; (2) implementation during instruction; and (3) reflecting after instruction. All of the participant teachers were observed in their natural teaching environment as they planned for, taught, and reflected on a series of lessons that used the new curriculum materials.

This study provides an overview of the teachers' classroom activities related to the new curriculum material. I examined the factors teachers consider when planning to use the new materials, how they enacted the instruction in classes, and how they reflected on their teaching during the instructional sessions. In particular, this study investigates what teachers think about and how they use the new curriculum materials to facilitate the teaching and learning practices they envision as they make sense of what students are doing. I believe that this form of research will give us an insight into the relationship between teacher and technology-based curriculum material.

Rationale

As teachers make decisions in the classroom, they constantly evaluate circumstances, identify problems, consider alternative courses of action, and respond to situations that arise.

Some decisions may be made before instruction (planning), others may be made during instruction (implementation), and still others may be made after instruction (reflection). The idea of attempting to describe and understand the thinking and decision-making processes that contribute to teacher effectiveness originated in a book entitled *Life in Classrooms* (1968) by Philip Jackson. He explained the complexity of teacher decision-making in terms of the three specific actions described above. His labels for these actions were pre-active, interactive, and post-active. In other words, teachers make decisions before, during, and after teaching in a linear fashion. He used the conceptual distinctions of pre-active, interactive and post-active stages of teaching to examine teachers' thoughts before, during and after teaching a lesson. Over the last three decades a great deal of theoretical and empirical research has been conducted based on this perspective on teaching (Artzt & Armour-Thomas, 1998, 2002; Clark & Peterson, 1986; Cobb, 2002; Leikin, 2005; Shavelson & Stern, 1981). Many of these decisions are carefully thought-out to meet curricular and instructional goals, and others are made spontaneously as teachers and students interact (Ryan & Cooper, 2000).

To date, several research studies have examined the decision-making processes of secondary level science teachers (Aikenhead, 1984; Park & Oliver, 2008). Previous research concerning decision-making focused on teachers' cognition, teachers' beliefs of the subject matter but paid little attention to the circumstances surrounding the introduction of new curriculum materials. In recent decades, many curriculum materials have been developed, and, as a result, a continuous flow of new and innovative curriculum materials is now available for use in science classes. Thus, it is meaningful to study teachers' decision-making processes that focus on the enactment of these new curriculum materials. The results of this research could provide relevant information about decision-making with regard to the development of a new curriculum.

If curriculum developers want to understand teachers' perspectives on how their decisions sustain and support the teachers' activities during instruction, then curriculum developers would be better served by interactions with teachers within the realities of classroom practice.

There are few general principles that apply to every situation because context matters and because a deep understanding that goes beyond the general principles of content, technology, and pedagogy is required. Rosenshine (1971) and Siegel (1977) both recommended that research on teaching be conducted within the context of curriculum packages, and Gage (1979) added that curriculum-specific research on teaching should proceed through observation of what teachers actually *do* with these curriculum packages. Therefore, this research design, which is being conducted within the context of 3-D inquiry-based case studies, will seek a deep understanding of the curriculum implementation process from the perspective of the teacher.

Teachers are constantly making decisions as their classroom environment changes. The decisions made by teachers influences both instruction and learning outcomes (Klimczak & Balli, 1995). Although student learning outcomes are outside the scope of the present study, curriculum developers or teacher educators can use the findings from this research as a reference in order to successfully prepare teachers to use new curriculum materials in their classrooms.

Research Questions

Understanding how teachers make sense of a new technology-based curriculum, how they choose the material to use with their students, and how they implement lessons based on those materials can inform researchers and those who prepare teachers about ways to better prepare and support them in the ways of both preparation and practices. This study provides comprehensible and practically useful research findings for science teachers by showing the experience of other teachers who may be in a similar situation. Also, this study may provide useful information for those developing materials for use with innovative technology-based curricula, so that the materials may be enhanced to better meet the needs of teachers. With these wishes in mind, I used the following research questions to guide the study:

1. What factors influence teachers' decision-making about the use of 3-D animation curriculum materials prior to implementing these materials into their classrooms?

2. How do teachers adjust their instructional actions for the specific classroom context when using these new curriculum materials?

3. How does reflection on the lesson affect the teacher's thinking with regard to future use of the specific module or other related animation-based curriculum materials?

Definition of Terms

In this study, curriculum materials refer to resources available to teachers and used by them for instructional purposes. Curriculum materials also refer to resources obtained online, supplemental textbooks and activity books, computer software and materials provided by colleagues or from other sources.

Technology for this study is defined as hardware related to computers, software applications that run on computers, and the Internet. Technology includes computers interfacing with other technology to create new methods of teaching content, and thus includes scanning images into computers and downloading video segments from websites.

Other terms are defined below.

- Decision making: Making well thought-out choices from among several alternatives based on judgments consistent with one's values and on the relevant, sound information available (Moore, 1998, p.8)
- Planning: The ways in which teachers decide what and how they want students to learn

- Implement a curriculum material: the ways in which a teacher takes a curriculum material or its guidelines or standards and enacts them in the classroom (Clarke, 2008)
- Reflection: Intentional and systematic consideration of one's own educational practice or being thoughtful about one's work (Roth, 2007). A structured process for reflection helps teachers think about what they see within the classroom, how they describe and analyze it, and how to respond to it in terms of student learning (Rodgers, 2002).

Summary and Preview

In this chapter I have discussed the underlying assumptions of this study, the purpose of the study, the research questions, and the rationale for the study. Chapter two provides research literature regarding teachers' planning, teaching, and reflecting. This review also includes teachers' use of curriculum materials, which informed the theoretical framework of this study. Chapter three describes the research design and analysis used in the study. A description of the participant teachers and their instructional context is provided as well. The findings from the research are presented in categories of planning, teaching, and reflecting in Chapter four. The final chapter, Chapter five, summarizes the study, discusses major findings, and provides implications for science teachers, curriculum developers, and science educators.

CHAPTER 2

LITERATURE REVIEW

In this chapter, I provide an overview of the two main strands of literature used as frameworks to inform this study. This review will be presented similar to the research itself in categories of planning, teaching, and reflecting so as to provide insights about the structures and content of teachers' teaching. This review will include teachers' use of curriculum materials, which also inform the theoretical framework of this study.

A large body of educational research literature has shown that teacher behavior is substantially influenced and possibly determined by teachers' thought processes. Clark and Peterson (1986) noted that there is a reciprocal relationship between the domains of thought and action and argued that a full understanding of the process of teaching will come only when the two domains are studied in relation to one another. Schoenfeld's model (1998) shows the key aspects of thought and action in teaching—the beliefs, knowledge, goals and sequence of actions implemented by the teacher to be analyzed in a specific teaching context—and allows one to understand how these aspects jointly interact.

Planning, conducting instruction, and reflecting about the enacted teaching create the instructional environment through which curriculum is interpreted and implemented. (Orlich et al., 1998). Research on teacher cognition has examined teacher thought processes before, during, and after teaching in an effort to understand the decisions they made, why they do what they do, and the cognitive processes they employ (Borko & Livingston, 1989; Clark & Yinger, 1979, 1987; Ethell & McMeniman, 2000; Griffey & Housner, 1991). While various terminologies have been used to describe what teachers do prior, during, or after teaching, for the purpose of this review I have chosen the following vocabulary to be consistent: planning, which is identified as those instruction-related activities happening during the pre-active stage; teaching, which is identified as those instruction-related activities happening during the interactive stage; and reflection, which is identified as those instruction-related activities happening during the post-active stage.

A review of the literature reveals that the research focusing on teacher thought has been studied in stages. For example the research about teacher planning was developed and conducted in the late 1970s through the 1980s. The majority of research on the act of teaching began in the 1980s and continued into the 1990s. Although the research on reflection has appeared sporadically in the literature, it has become a major focus in recent years. For the purpose of this study, the sources of literature will be addressed within the following four main strands: planning and decision making, teaching, reflecting, and teachers' use of curriculum materials. However, most of the research that was examined was linked to planning process, but few research studies linked to teachers' use of curriculum materials also were examined.

While discussing the planning, I review the literature on teacher thought processes in order to build on the research conducted by Clark and Peterson (1986) and Shavelson and Stern (1981). These authors constructed a schema of teacher thought process and action that is very well organized, and their work is still used in research performed today (Artzt & Armour-Thomas,2002; Ball et al., 2008; Henze, et al., 2009; Hermans et al., 2008; Moreno, 2004). Then, literature on teacher teaching and reflection is reviewed. Finally, the literature related to teachers' use of curriculum materials is reviewed to inform the theoretical framewok for this study.

Teacher's Instructional Planning and Decision-Making

The concepts of decision-making and planning have a historical bas in the research literature on teaching. Traditionally, teaching has been viewed as a decision-making process. For example, Lienhardt and Greeno characterize teaching as:

> *a complex cognitive skill requiring the construction of plans and the making of rapid on-line decisions. The task of teaching occurs in a relatively ill-structured, dynamic environment. Goals and problem-solving operators are not specified definitely, the task environment changes in a way that is not always under control of teachers' action and information appears during the performance that is needed for successful completion of the performance. (1986, p.75)*

Borko, Cone, Russo, and Shavelson state:

> *Teaching, then, can be characterized as a process of decision-making sometimes teachers are aware of their decisions, and sometimes they make them automatically. From this perspective each teacher has a repertoire of teaching strategies and materials that are potentially useful in a particular teaching situation. The choice of a particular strategy depends on the teacher's goals for the lesson, beliefs about teaching, and information about the students. (1979, p.138)*

And, then these authors go on to discuss the consequences of such a view of teaching:

> *When teaching is viewed as a decision-making process, the teacher is seen as an active agent who selects a teaching skill or strategy in order to help students reach some goal. The choice may be based on one or more factors. If all the types of information mentioned above were used, teachers would need to integrate the large amount of information about students from a variety of sources and somehow combine this*

> *information with their own beliefs and purposes, the nature of the instructional task, the constraints of the situation, and so on in order to select an appropriate instructional strategy. (1979, p.139)*

Other research has suggested that what teachers think about prior to teaching shapes what they do in the classroom (Carnahan, 1980; Clark & Peterson, 1986; Clark & Yinger, 1987). Research also has indicated that planning serves as a guide or mental image for the lesson that, in turn, influences the content covered, the focus of lessons, learning opportunities provided, and the organization of students and teacher-student interaction (Carnahan, 1980; Griffey & Housner, 1991; Hill, Yinger, & Robbins, 1981; Peterson & Comeaux, 1987).

Yinger (1979, 1980) and Clark and Yinger (1979) have determined that during the course of a school year, experienced teachers engage in as many as eight different types of planning: weekly; daily long range; short range; yearly; term; unit; and lesson planning. As a component of this research, Yinger showed that routines are a principal product of teacher planning and suggested that teachers respond to the pressures for simplification and efficient time management by planning. Yinger defined routines as sets of established procedures for both teacher and students that function to control and coordinate specific sequences of behavior. “Routines played such a major role in the teacher’s planning behavior that planning could be characterized as decision making about the selection, organization, and sequencing of routines” (Yinger, 1979, p. 165). He also identified four types of routines as products of teacher planning: (a) activity routines, (b) instructional routines, (c) management routines, and (d) executive planning routines. The relative importance of different types of planning was also explored by Clark and Yinger (1979). Unit planning was cited most often by the teachers as most important, followed by weekly and daily planning.

The issue of relationships among decisions made during the pre-active, interactive, and post-active stages had not garnered much attention until the major summary of research published by Clark and Peterson in 1986. Clark and Peterson coded and counted types of decisions according to a categorization of the factors upon which the decisions were based. The first important criterion used to distinguish types of decision making in their studies is whether decisions are made in preparation for the classroom, or whether they are made in the classroom. This distinction played an important role in defining and delimiting areas for subsequent research. Clark and Peterson (1986) linked the two areas and showed how pre-active plans are communicated, reconstructed, or abandoned in the interactive teaching environment.

In light of this initial distinction made between teachers' pre-active decision-making and teachers' interactive thinking, researchers typically attempted to categorize the types of factors considered by the teachers. In both of these areas, four broad categories or types of decisions were identified: objectives, content, instructional processes and learners. According to Clark and Peterson's summary of this research, in pre-active decision-making, subject matter content is of primary importance, followed by instructional processes and then objectives. However, during the interactive phase of teaching, the order of the thought processes is reversed, with learners being of primary importance, followed by the instructional processes finally content (factual information). For some, subject matter means a particular set of skills; for others it means a set of ideas or concepts; for still others it may mean a way of reasoning about certain kinds of problems.

The most obvious function of teacher planning is to transform and modify the curriculum to fit the unique circumstances of each teaching situation. In the research by Clark and Elmore (1981), one teacher reported that the primary resources that she used in the activities related to assembling her yearly planning were curriculum materials, memory of classroom interactions during the previous year, and the calendar for the coming school year. The study of yearly planning supports the idea that published curriculum materials have a powerful influence on the content and processes of teaching.

Research by Duschl and Wright (1989) found that high school teachers' planning decisions were dominated by considerations such as the level of the students, the objectives as stated in the curriculum guide, and the pressures of accountability. Their study also concluded that teachers "hold a view of science that does not recognize theories or theory development as centrally important in the scientific enterprise," (Dushl & Wright, p. 493) and thus their understanding of the nature of scientific theories is not an important part of their planning.

Principal points from the research related to planning are as follows:

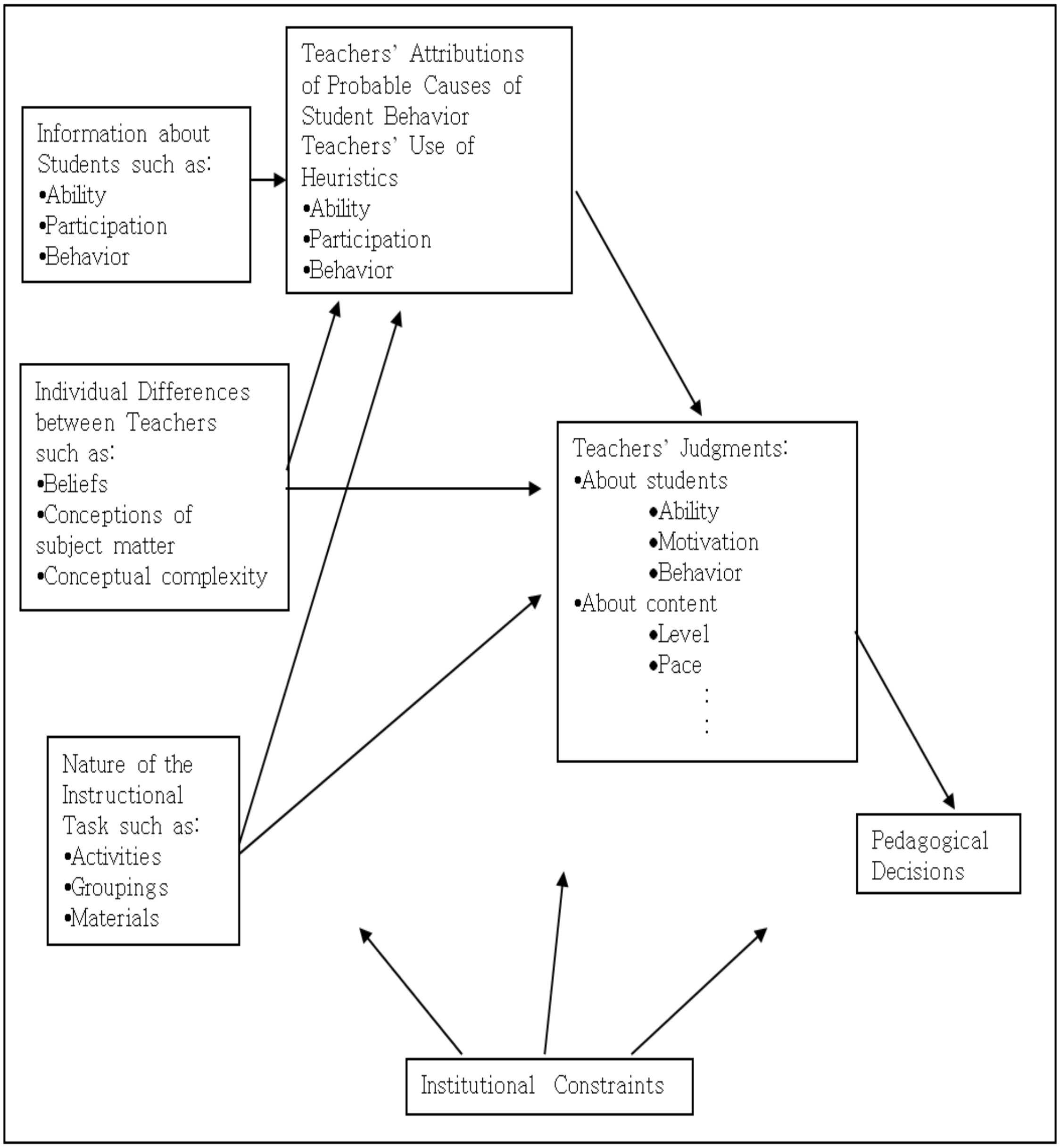
- Teaching is a complex process which demands conceptualization on the teacher′s part of what will probably take place during the instruction phase (Clark & Yinger, 1987; Bellon et al., 1992).
- The primary function of planning is to provide the students with a good opportunity to learn. Careful planning makes it possible to make instructional adjustments that answer the needs of students. At the same time, there is a greater chance that the material will be taught in the allocated time (Bellon et al., 1992).
- Activities appear to be the most salient feature and they constitute the building blocks of planning (Shalveson, 1987), although the content is usually the starting point according to many studies (Clark & Peterson, 1986). Duschl and Wright (1989) suggested that scientific theories are not the determining feature in the planning decisions made by teachers.

- During the school year, teachers plan in accordance with the period they intend their planning to cover and the volume of material to be programmed (Clark & Peterson, 1986). Unit planning is one of the most frequent and important tasks for teachers. Better learning usually results when teachers plan units carefully with the aim of achieving objectives based on the content and students' needs (Clark & Yinger, 1987).
- Planning is a cyclic, continuous, and interactive process which occurs in three overlapping phases (pre-active, active, and post-active) (Yinger, 1977). It begins with a general idea in the form of a problem that is resolved by the progressive elaboration of plans (Bellon et al., 1992).
- Knowledge based on previous teaching experience determines how teachers plan their teaching (Aikenhead, 1984), although most teachers base their lessons on the teachers' version of the textbook that accompanies the students' textbook (Bellon et al., 1992). When teachers control and adjust their plans to the progress made by students, there is a positive effect on learning (Calderhead, 1984; Berliner, 1988).

Shavelson and Stern (1981) identified some important factors that may affect teachers' pedagogical decisions (Figure 1). Teachers have available a large amount of information about their students from many sources such as their own informal observations, anecdotal reports of other teachers, standardized test scores, and school records (Borko et al., 1979; Rudman et al., 1980; Shavelson, 1978; Shavelson, Atwood, & Borko, 1977). To avoid information overload, teachers integrate this information into judgments about their students' cognitive, affective and behavioral states (Borko et al., 1979; Everhart, 1979; Morine-Dershimer, 1978; Shavelson, 1978). These judgments, in turn, are used to make pedagogical decisions.

Figure 1

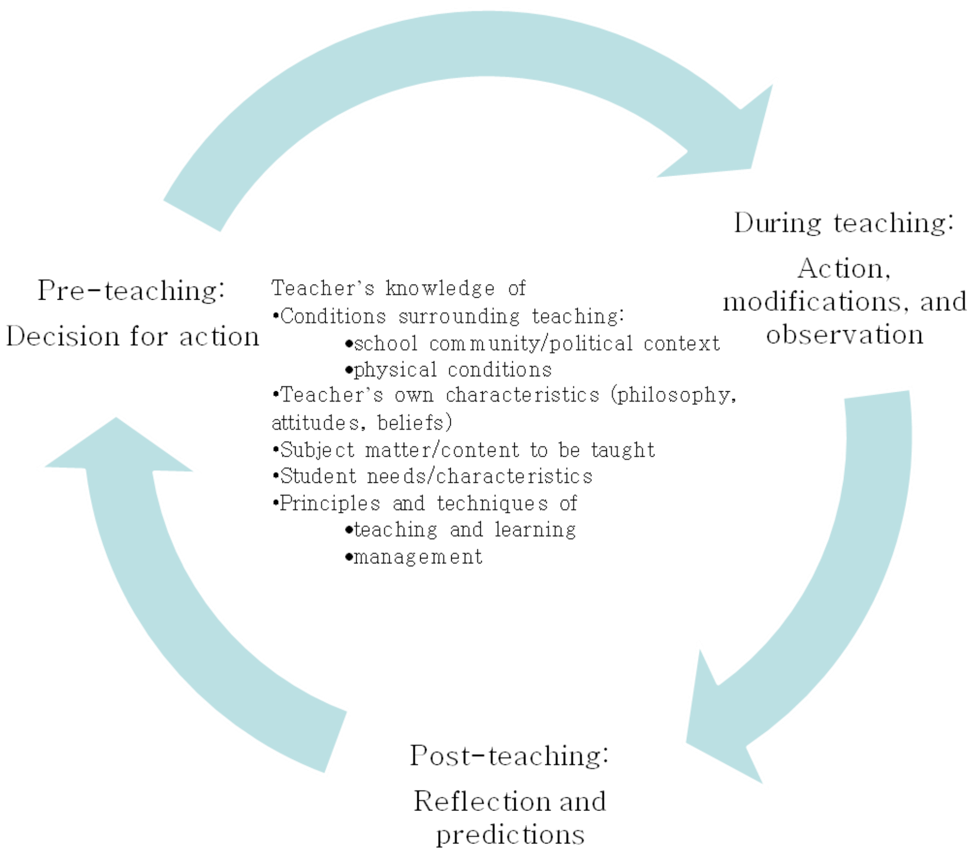
Some Factors Contributing to Teachers' Pedagogical Judgments and Decisions (from Shavelson & Stern, 1981)



Pasch et al. (1991) presented the decision-making model shown below in Figure 2. In the center are listed the factors to consider when teachers make any teaching decision and when teachers interpret the effects of their decisions. The three phases of teachers' reflective thinking are shown as a continuous process of decision making: (1) pre-teaching decisions for action, (2) teaching action, modifications, and observation of their effects, and (3) post-teaching reflection and predictions about future actions.

Figure 2

Factors Considered in Teaching Decisions and Reflections (from Pasch et al., 1991)



Research that focuses on how science teachers make decisions appears to mainly consider teachers ideas about what aspects of the subject matter are to be taught. Whether or not a teacher's understanding of the nature of science is necessarily reflected in planning for instruction and/or classroom practice is largely an academic question. This question has been researched thoroughly, and although disagreements still exist, most research agrees that such reflection is not automatic and is extremely complex in nature (Abdel-Khalick, Bell, & Lederman, 1998). For example, Lederman (1999) indicated that teachers' conceptions of science do not necessarily influence classroom practice. In Lederman's study, of critical importance were teacher's level of experience, intentions, and perceptions of students. Overall, the research was consistent with emerging findings about the relationship between teachers' understandings and classroom practice, as well as the research indicating the importance of explicit instructional attention to nature of science(NOS). Although it is now clear that teacher's conceptions do not generally translate into classroom practice, concerns about teachers' conceptions persist.

Table 1

The Endeavor to Understand Teacher Decision-Making in Science Education after the 1980s

	Study	Teachers	Findings
Relationship between Teachers' conceptions and instructional behaviors	Brickhouse (1989, 1990)	Three secondary science teachers	Two of three (both experienced) exhibited classroom practices that were consistent with their personal views, one beginning teacher's practice were not congruent with the belief
	Duschl & Wright (1989)	13 science teachers in a large urban school	The nature of science is not integral components in the influences affecting teacher's educational decisions.
	Lederman & Zeidler (1987)	18 high school biology teachers from nine schools	There was no significant relationship between teachers' understandings of NOS and classroom practice.
	Hammrich (1997)	8 teacher candidates who enter the science	Teacher candidates' conception of the nature of science is linked to how they learn science

		methods course	material. Teachers' views toward the nature of science are often considered as an important factor that frames their teaching beliefs, and these views may be related to instructional practice
	Bell et al. (2000)	Thirteen preservice secondary science teachers	NOS instruction and activities they experienced in their science methods course did not help them address NOS instructionally during student teaching in the context of science content that was different from that explored in the methods courses.
	Abd-El-Khalick (2001)	30 female elementary education majors enrolled in physics course	Learning about NOS in the context of science content courses may facilitate the translation of teachers' NOS views into instructional practice. (this claim needs further examination and validation)
Teacher belief on curriculum implementation	Cronin-Jones (1991)	Two middle school teachers	In both teachers' cases, four major categories of beliefs (about how students learn, a teacher's role in the classroom, ability levels of students, the relative importance of content topic) influenced the curriculum implementation process.
	Aikenhead (1984)	Five high school science teachers	Teachers appeared to make decisions within a framework that holistically integrated science content and practical classroom knowledge. The decision represented the end result of the conflict between a cluster of teacher

	intentions and a mélange of ideas about student characteristics

Table 2

Variables to Mediate and Constrain the Translation of Teachers' Conceptions into Practice

	Lantz & Kass, 1987	Duschl & Wright, 1989	Brickhouse & Bodner, 1992	Hodson, 1998	Gess-Newsome & Lederman, 1995	Abd-El-Khalick et al., 1998
Pressure to cover content		O		O		O
Classroom management and organizational principles	O			O	O	
Concerns for students' abilities and motivation		O	O		O	O
Institutional constraints			O			
Teaching experience			O		O	
Discomfort with understandings of NOS						O
Lack of resources and experiences for assessing understandings of NOS						O

O: Author includes this variable as a component of constraints

Teaching

Marx and Peterson (1981) determined that teachers who made the most decisions in planning tended to do the least decision-making in teaching, whereas those who made the most decisions during teaching had made the least number of decisions in planning. They also reported that teachers' lessons followed the focus of their plans. For example, if subject matter was a focus in planning, it was evident in teaching. Those teachers who set goals in their planning focused on these same goals in their teaching.

Research suggests that experienced teachers seem to use the agendas they created during planning as a guide to their actions while teaching. They referred to these plans during the lessons to ensure that they remained on track, or they worked from mental scripts. They also used these guidelines as they made connections between student understanding and the concepts and skills that were enumerated for the objectives of the lesson. This flexibility allowed them to fill in the outlines during teaching to ensure that their instruction was responsive to actual student understanding and performance (Borko & Livingston, 1989; Leinhardt & Greeno, 1986).

In contrast, novice teachers made decisions based on their written plans more than on the needs of the students. In fact, beginning teachers typically encountered problems when students did not respond as they anticipated, causing a potential detour from their written plans. Interestingly, the beginning teachers often continued to follow the set plan, as they were unaware of alternative paths that their decision making might lead them to (Borko & Livingston, 1989; Graham, et al., 1993; Westerman, 1991). Byra and Coulon (1994) reported similar findings in a study of preservice teachers. In addition, they also identified a distinction between experience levels of the preservice teachers; the more experienced preservice teachers tended to make some adjustments if their lessons were perceived to not be progressing as planned.

Decisions made during teaching differ from decisions made during planning. Typically, the decisions made during teaching are made without the time to reflect or to seek additional information (Borko & Shavelson, 1990). The success of an experienced teacher making spur-of-the-moment decisions or improvising requires that the teacher have an extensive network of interconnected, easily accessible schemata (structured frameworks/plans). In addition, the teacher must have the ability to select particular strategies, routines, and information from these schemata during actual teaching (Borko & Livingston, 1989).

Research on teacher thinking has attempted to describe what decisions teachers make that lead them to change their plans or their behaviors in the classroom. Further, research has also sought to answer how often teachers made these decisions and what stimulated the decision making process (Clark & Peterson, 1986). Several studies provided evidence that the greatest percentage of thoughts teachers made during the act of teaching were concerned with students (Marx & Peterson, 1981). These decisions involved observation of student cues including the assessment of student behaviors, student cognition, student affect, and other student characteristics.

Reflection

The first real relationship between education and reflection can be found in the work of John Dewey in the early 20th century. Dewey (1933) linked the notion of reflection to how we think and to two types of teacher action: the routine and the reflective action. The theoretical concept of reflection as described by Dewey (1933) is “active, persistent and careful considerations of belief or supposed form of knowledge in light of the grounds that support it and further conclusions to which it tends” (p. 6). In addition, he highlights three areas or prerequisites in attitude that must work in collaboration with reflection: open-mindedness to alternative possibilities, consideration of consequence, and whole-hearted willingness to put ideas into practice.

In contrast, Van Manen (1977, 1995) suggested that within self-reflection, there are three levels of reflectivity: (1) *technical,* defined as a means to reach an end or goal; (2) *practical,* representing the process of review and analysis of meaning, assumptions and perceptions or informing practical actions; and, (3) *critical,* defined as the highest level, questioning the status quo, or relating to moral, ethical and political aspects of the education. In a study of four experienced elementary and secondary physical education teachers, Tsangaridou and O'Sullivan (1997) attempted to describe teachers' reflections using the terms micro-reflection and macro-reflection. Micro-reflection was reflection that informed teachers' day-to-day practices and addressed pedagogical content, ethical, moral, and social issues. The researchers found micro-reflections to be situationally driven and contextually bound. Macro-reflection was the term used to define the type of reflection that informed teachers' practices over time and thus influenced changes in the teachers' classroom practices and professional development.

The third and possibly most influential discussions and understandings of reflection originate from the work of Schön (1983, 1987). Schön proposed using the terms reflection-in-action and reflection-on-action as the constructs of reflection as a whole. As the terms suggest, reflection in-action refers to the process of analyzing and interpreting during action, as opposed to reflection-on-action, when one mentally reconstructs and analyzes prior events.

However, it must be noted that the majority of research addressing the issues of reflection are studied in the area of theory. Little research has examined the practical implications of reflection on teaching. It is important, therefore, to remember that the way professionals solve problems and construct professional knowledge is a process "whose underlying structure is the same: A reflective conversation with a unique and uncertain situation."(Schön, 1983, p.130). Therefore, a teacher's action of planning includes not only the thought processes that teachers engage prior to teaching but also the thought processes or reflections that they engage during and after classroom interactions. Returning to Yinger's (1980) study, Yinger maintained that the third stage in his cyclic planning model involved implementation, evaluation, and eventual routinization of the plan. Reflection could well be the process leading to evaluation and to eventual routinization that guides teachers' thinking.

It is believed that some individuals are more inclined to be reflective than others (Bolt, 1996; Gore, 1990; Rovegno, 1992). In an attempt to study reflective practices, most of the research compared experienced and novice teachers. Experienced teachers relied heavily on reflections from past lessons to plan new lessons (Graham, et al., 1993). The ability to recall is a key to reflection. In a study by Peterson and Comeaux (1987), experienced teachers both recalled more classroom events and relied more often on procedural knowledge and principles of analyzing than did novice teachers. In a similar study comparing the evolution of accuracy and thoroughness of novice, intermediate and experienced teachers' ability to recall their own as well as their students' behaviors, Allen and Casbergue (1997) found that individual teachers progressed in thoroughness of recall along different paths and at different rates. In general, novices and intermediates displayed only minimal accuracies in their recall of their own and their students' behaviors while the experienced teachers were extremely accurate.

Other discrepancies define inexperienced and experienced teachers' reflection practices. Inexperienced teachers tended to use only the lesson of one day to determine if the plans for the next lesson should be modified (Graham, et al., 1993). In a study by Borko and Livingston (1989) novices reported more varied but less selective post-lesson reflections than experienced teachers. These findings contrast with a study by Allen and Casbergue (1997) in which teachers were characterized as experienced, intermediate, or inexperienced. For the intermediate group, if inaccuracies in recall occurred, they were in relation to recall of their own behaviors while the inexperienced teachers made more recall errors about the behaviors of the students. Additionally, just as experienced teachers have a tendency to teach according to initial goals determined in planning, their reflection appeared to focus on these same original goals.

The reactions to lessons that experienced teachers shared with Livingston and Borko (1989) were concise, focused primarily on student comprehension, and mentioned only those events believed to impact the accomplishment of instructional goals. The experienced teachers reported that their own effectiveness was rarely assessed. In contrast, novices' post-lesson reflections addressed many more concerns. All three novices were attentive to primarily their own teaching. The only observation made of students was regarding student activity level.

There have been suggestions that the best way to get teachers to change their teaching practices is to change their general conceptions. It has been proposed that this change occurs through a process of conceptual change (Posner, Strike, Hewson, & Gertzog, 1982), and that can only be accomplished through reflection. Similar to students, however, teachers do not frequently engage in this type of reflection: thus their general conceptions tend to be highly resistant to change.

Teacher-Curriculum Relationship Framework

This study was informed by Remillard's (2005) framework of interactions within the teacher-curriculum relationship. In addition to using Remillard's framework, I used M. W. Brown's (2009) design capacity for enactment framework to focus on how teachers use instructional materials. A research design was created to investigate whether the technological curriculum materials and teachers can be understood within these frameworks.

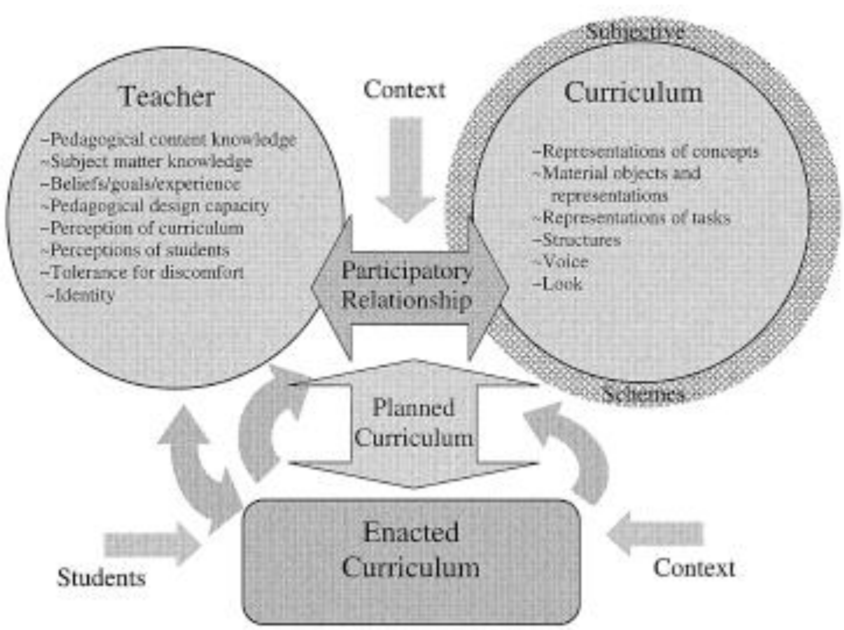
Remillard (2005) conducted an extensive review of research on mathematics curriculum use. That review revealed four major conceptions of curriculum use: following or subverting, drawing on, interpreting, and participating with. From this body of research and her own work, Remillard developed the teacher-curriculum relationship framework (Figure 3). She reported that teachers consider their own experiences and contexts as they read, interpret, evaluate, and adapt a curriculum.

This framework highlights the interaction between the teacher and instructional resources. There are four major constructs in the framework: the teacher, the resource, the participatory relationship, and the planned and enacted curriculum. The left-hand circle of the framework represents the resources, stances, and perspectives that the teacher brings to the relationship with curriculum resources. These include the individual characteristics discussed in the literature reviewed earlier, such as knowledge, capacities, beliefs, perceptions, and experiences. The right-hand circle represented the particular curriculum resource or text being used. The outer ring presented the curriculum as a subjective scheme—how the curriculum, its particular features, and curricula in general are perceived by the teacher and within the broader society. Remillard differentiated between the planned curriculum and the enacted curriculum. The planned curriculum is the outcome of the participatory interactions between the teacher and the curriculum resources. The enacted curriculum expresses these plans as they unfold in a particular classroom context with particular students.

Remillard emphasized the participatory relationship between teachers and curriculum as the most accurate conception of curriculum but also implied that the interpretation and conceptions of curriculum use are embedded within this participatory relationship. The emphasis on the relationships among these four components “allows the framework to represent the cycles of design before, during, and after classroom practice” (Remillard, 2005, p. 236). The relationships also illustrated the dynamic and iterative nature of teaching and instructional design. For instance, enacting a planned lesson may lead to in-the-moment decisions, which in turn lead to a new plan of action for the lesson, which produces a different enactment (Remillard, 1999). These types of cycles can also lead to changes in teacher characteristics such as beliefs and perceptions about students (Remillard, 2000).

Figure 3

The Teacher-Curriculum Relationship Framework



From “Examining Key Concepts in Research on Teachers’ Use of Mathematics Curricula,” by J. T. Remillard, 2005, Review of Educational Research, 75, p. 235. Copyright 2005 by the American Educational Research Association.

As illustrated in Figure 3, both the teacher and the resources bring a variety of characteristics to the relationship. Remillard proposed this framework as a lens through which to view how each element leads to differences in curriculum materials use and the planned and enacted curriculum. Even though the context is not a primary construct of the framework, Remillard suggested the relationship be studied in particular contexts, both local school and classroom contexts as well as more global policy contexts.

Given the importance of the participatory relationship between teacher and curriculum in her framework, Remillard (2005, 2009) often referred to Brown's (2009) design capacity for enactment framework. Brown conceptualized teaching as "a process of design in which teachers use curriculum materials in unique ways as they craft instructional episodes" (p. 18). He proposed his framework as a nonevaluative tool for studying how teachers use materials and how designers can create materials that influence teaching practice. He proposed that how teachers engage with materials— selecting, interpreting, and reconciling personal goals with those in the materials; making contextual accommodations; and modifying materials—is influenced both by teacher characteristics and by the design of the materials. Also, he emphasized that this relationship is cyclical in that the curriculum influences teachers and that the teachers interpret and use the materials through their unique lens.

To analyze how teachers use resources, Brown (2009) developed a scale according to ways or degrees of materials appropriation: offloading, adapting, and improvising. The scale focused on the level of shared authority between teachers and the instructional materials. Brown specifically stated that none of the three types of materials use is negative. Any decision on using curricular materials in a specific way must be viewed in terms of the teacher's goals and the value of the particular resources. Also, because of the dynamic nature of teaching, it is possible to engage in offloading, adapting, and improvising within a single class period. The value of Brown's framework as a tool is in characterizing "the nature of a teacher's interaction with a given resource, but it does not evaluate the outcomes of this interaction" (p. 25).

The first degree of materials appropriation is offloading, which Brown and Edelson (2003) defined thus: "Offloads are shifts of curriculum design responsibility to the materials" (p. 6). This type of materials use is common when teachers are unfamiliar with the content or pedagogy called for in the materials or when they are unfamiliar with the materials themselves. Examples of offloading include logistical pedagogical decisions such as using readymade materials with one group of students while others use learning stations in the classroom. Additionally, teachers may offload materials that they perceive as well written and aligned with their own beliefs, curriculum standards, and the needs of their students.

In the middle of the scale is curriculum adaptation, a more equal sharing of the responsibility of curriculum design between the teacher and the materials. Adaptation occurs when teachers use certain elements of the materials but also contribute their own design elements. This type of materials appropriation is used to account for contextual factors such as student needs and classroom constraints as well as to better align instructional materials with learning goals. Teachers may also adapt materials to engage students in student-centered rather than teacher-centered instruction, or vice versa (Brown, 2009; Brown & Edelson, 2003).

At the other end of the continuum from offloading is improvisation. In this form of appropriation, the teacher is the primary designer of the learning activity. That is, he or she may take an idea from a published resource, but the resulting instruction and class activities may represent a complete departure from the written materials themselves. Often an improvisation is deliberate (Brown, 2009; Brown & Edelson, 2003) and can be either planned before instruction or occur during instruction, as a part of the dynamic relationship between the planned and enacted curriculum.

Brown (2009) claimed that the design capacity for enactment could be used in a nonevaluative manner to describe how teachers interact with instructional materials. He also claimed, however, that studying how teachers use materials might highlight an evaluative aspect of their work: pedagogical design capacity.

> Although the [design capacity for enactment] framework accounts for the resources contributed by the teacher and the curriculum materials—the nouns of the interaction, as it were—it does not fully account for the actions involved in their mobilization—the verbs of the interaction. … [The teacher] possesses a skill in perceiving the affordances of the materials and making decisions about how to use them to craft instructional episodes that achieve her goals. (p. 29)

Pedagogical design capacity explains not only how teachers evaluate materials but also how they balance science and pedagogy to devise strategies to accomplish their specific instructional goals. Pedagogical design capacity focuses on teachers' abilities to mobilize their knowledge and their ability to design appropriate learning experiences.

Beliefs and experience contribute to a teachers' pedagogical design capacity (Brown, 2009). Because teachers' beliefs about students, science, and teaching contribute to their selection of appropriate materials and teaching strategies, those beliefs and goals are important considerations in understanding how teachers evaluate, select, and use instructional materials. Additionally, because pedagogical design capacity may develop over time, greater familiarity with specific materials and the instructional strategies employed in those materials may also result in an improved ability to use those materials to meet one's instructional goals.

Teachers and Technology-Based Curriculum Material

Curriculum materials have been given highly varied degrees of importance at different times and in different contexts. The attempts to introduce inquiry science education in the 1960s, for example, were centered on innovative new curriculum materials (DeBoer, 1991). The curriculum materials were developed with the expectation that almost any teacher could use them easily in the classroom in a manner that would result in inquiry learning and student understanding of science as inquiry. In general, none of the materials lived up to this expectation.

On the other hand, the particular materials selected are sometimes thought to be of little importance, at least in the hands of a good teacher (Orlich et al., 1998). It is assumed that what happens in the classroom depends upon the teacher, and if the teacher is competent, it doesn't make much difference what materials are used. Neither of these extremes is a good grounding for introducing positive educational changes. Quality inquiry science materials are of major importance and influence in classrooms; they can be the foundation of quality education. On the other hand, the materials themselves will not do the job independent of a well-qualified teacher.

The desired materials reflect the vision of science education found in the standards of such documents as the *National Science Education Standards* (NRC, 1996) and *Benchmarks for Scientific Literacy* (AAAS, 1993). In particular, these curriculum materials should have the following four distinguishing characteristics:

1. Are standards-based in that the science content, instructional strategies, and assessment tools optimize student learning as reflected in current research on teaching and learning;
2. Are inquiry-based, which includes support for inquiry as a teaching strategy as well as the inclusion of content that addresses the abilities to do inquiry and the

understandings about science as inquiry;

3. Are based on a carefully developed conceptual framework that reflects the science disciplines and connects factual information to larger ideas, themes, and concepts; and
4. Are revised as a result of thoughtful and comprehensive field testing, which provides developers with data about the effectiveness of the materials used by teachers and students. (Powell & Anderson, 2002, p.114)

Assuming that the materials themselves are of high quality—such as one would expect from a process with the four characteristics given above—the materials themselves make demands on teachers that are both substantial and meaningful. The best materials ask teachers to conduct their classes in a manner that is far from routine, introduce multiple forms of inquiry, and lead to student engagement and empowerment. As a result, teachers are encouraged to move out of their comfort zone, attempt new practices, and challenge some of their personal values and beliefs. Teachers have to be the focal point of a move toward more inquiry-oriented science education (Anderson, 2007).

Butts, Koballa, and Anderson (1993) surveyed 125 primary and 150 intermediate teachers over two years. They reported that most teachers supplemented their textbook with other materials for alternative and additional instructional ideas:

> If teachers believe that science topics are of interest to their students and that these topics will help their students achieve goals in science that the teachers' value and that are part of the expected curriculum, then teachers will find time to schedule the use of these materials with their students. The teachers' internal beliefs about what is beneficial for their students linked with the external constraints of their students' interests and the

expected curriculum are the factors that govern a teachers use of instructional materials… teacher are not likely to use these resources if they believe that they do not fit the "gotta do's" of the expected curriculum. (p. 357)

Wagner-Gershgoren (2004, p.504) clustered teachers' criteria for choosing and evaluating biology textbooks into three groups:

1. Scientific content: the teachers attributed the highest degree of importance to the quality of the scientific content
2. Technical aspects: the teachers attributed the highest degree of importance to the format of the book
3. Didactic aspects: the teachers attributed the highest degree of importance to illustrations and organization of data (illustrations, pictures, graphs, flow charts, and schemes and tables.)

Many curriculum materials have been developed based on principles that are consistent with what is known about teaching and learning. Singer, Marx, Krajcik, & Chambers (2000) described a set of design principles that, when used to create standards-based curriculum materials, could engage students in inquiry, make use of new learning technologies, and promote student learning. Singer, et al. (2000) determined that seven curriculum principles—context, standards based, inquiry, collaboration, learning tools, artifacts, and scaffolds—derived from features of social constructivism are consistent with recommendations by the AAAS and NRC. In their study, they suggested curriculum materials created using these principles can promote deep understanding of science concepts and inquiry strategies.

The definition of curriculum, according to a number of studies, has been of concern and offers challenges for developing one with universal standards. Sometimes, curriculum is defined to mean syllabus and text, which is a narrow definition. Howson, Keitel, & Kilpatrick (1981), noted that curriculum, therefore, must mean more than just the syllabus—it must encompass aims, content, methods, and assessment procedures of an educational activity. Kilpatrick (1996) defined curriculum as “an amalgam of goals, content, instruction, assessment and material” (p.7). Curriculum material, therefore, refers to helpful resources that teachers and students use to enhance the learning and instruction of science.

Curriculum materials can have a great impact on teacher learning. The way their influence plays out depends on the nature of the materials used. On the same point Remillard (2000) suggested that “materials most likely to foster learning are those that engage teachers in these processes” (p. 331). Ball and Cohen (1996) described some of the roles that curriculum materials could play in promoting teacher learning with the goal of supporting educational reform. Curriculum materials could support teachers’ learning of subject matter (Ball & Cohen, 1996; Schneider & Krajcik, 2002). Schneider and Krajcik (2002) found that teachers read, understood, and adopted ideas from the curriculum materials that they were using that supported the subject matter.

Other studies by Heaton (1992) and Remillard (1992) have come up with the contrary findings that curriculum materials may not lead to teacher change. They suggest that one participant teacher could make changes to his current curriculum and teaching strategies with a focus on applications, without making major changes in his pedagogical practices or beliefs about mathematics, teaching, and learning. Findings from their studies suggest that curriculum materials do not always enhance or support teachers learning. However, regardless of whether teachers learn through the use of curriculum materials, the introduction of innovative curriculum materials may have a significant impact on teacher knowledge. Enacting the curriculum first requires teachers' to know about the curriculum material. Generally, teacher learning involves developing and integrating one's knowledge base about content, teaching, and learning; becoming able to apply that knowledge in real time to make instructional decisions; participating in the discourse of teaching; and engaging in a range of teacher practices (Davis & Krajcik, 2005). Teachers need strong subject matter knowledge but must also develop pedagogical knowledge and pedagogical content knowledge –that is, knowledge of how to teach the content (Shulman, 1986). Teachers like any learners must also integrate their knowledge (Davis, 2004; Linn, Eylon & Davis, 2004). They need to make connections between ideas, in addition to adding new ideas about subject-area concepts, instructional approaches, students' ideas, and teaching principles.

From a Vygotskian perspective, it appears teacher behavior may be influenced by and determined by teachers' thought processes. Planning, teaching, and reflecting make up the instructional environment through which the curriculum is interpreted and acted upon. The research on teacher cognition has examined teacher thought processes before, during, and after teaching in an effort to understand the decisions they made, why they do what they do, and the cognitive processes they employ (Borko & Livingston, 1989; Clark & Yinger, 1979; Ethell & McMeniman, 2000; Griffey & Housner, 1991).

A study by Edwards (1995) using *University of Chicago School Mathematics Project* material with seventh and eighth-grade students investigated the impact of curriculum material on the development of cooperative learning and change in teachers' practices in two middle schools. They determined that teachers changed their instruction practices as a result of using the materials. These teachers' daily interactions with the innovative textbook and materials, their students, and their students' reactions to the materials required them to interpret the innovation on a regular basis. This may well have provided a source of continuing perturbation in their understanding of their own practices, and the resolution of any such perturbation may well have resulted in changes to instructional practice (Edwards, 1995).

Visualization in Science education

Scientific visualization including animations, computer-generated displays, simulations, and videos is being used increasingly in classrooms to help student gain understanding to phenomena and processes. The book by Gilbert (2005) collected research around these new tools, and a body of research is developing. Visualization has numerous applications in chemistry and most of the studies were in chemistry and general science. In relation to the educational effectiveness of scientific visualizations as used in classrooms, the findings of the studies are controversial in regard to the degree of support for students' development of the key scientific concepts that are encouraged and the degree to which this support represents an important goal of science education (e.g. Frailich, Kesner & Hoffstein, 2009; Geelan,2012; Lee et al., 2010).

In Lee's study (2010), the participant teachers implemented some inquiry units having many features including instructional guidance, embedded assessments, discussions, and highly detailed visualizations. The results showed that well-designed inquiry science units can improve student understanding of complex topics across science courses and teaching contexts. On the other hand, Geelan (2012)'s study showed that students gained no more benefit from scientific visualizations than from more traditional modes of classroom teaching involving teachers explanations, static diagrams on the board and class discussions. Geelan, however, suggests that at least the evidence does not make a case against using visualizations in classrooms. The evidence that students find learning with visualizations enjoyable and engaging (Annetta et al., 2009; Delgado & Krajcik, 2010) may in itself provide a solid motivation for teachers to use them.

Some studies provide further insight into the characteristics of students who benefit most from specific visualizations. For example, Huk (2006) studied the educational value of three-dimensional visualizations in cell biology. The inclusion of complex 3-D models of plant and animal cells most benefited students with high spatial visualization ability by supporting the recall of auditory and visually presented information. However, the addition of the 3-D model resulted in cognitive overload for students with low spatial visualization ability.

One study in particular underscores the importance of explicit instruction to ensure effective use of visualizations in science. Linn (2003) found that visualizations are useful for interpreting ideas. However, without instruction in visualization techniques, students often experience difficulty interpreting three-dimensional information. She discovered that learners may be confused by scientific visualizations because they do not have the same background knowledge as the people who created the visualizations.

Another study showed that the most effective applications of visualization in science are supplemented by textual or verbal information. Mayer and Anderson (1991) found that the combination of visualization (animation) and verbal or textual information enhanced understanding of scientific explanations and concepts.

Answers to questions about the place and importance of curriculum materials is dependent upon the given context and situation (Powell & Anderson, 2002) In the study that is the focus of this dissertation, the teachers had an opportunity to use a new technology-based curriculum material, reflect on their teaching with the material, and think about changes in their classroom practice. I predict the findings will contribute new understandings by describing the relationship between teacher and curriculum materials in todays' technological classroom environment.

Summary

This chapter discussed the literature and theoretical underpinnings that informed the present study. The review of literature focused on two areas of scholarship: teachers' three instructional stages (planning, teaching, and reflecting) and teachers' use of curriculum materials. This review provided insights about the structure and content of teachers' teaching and also informed the theoretical framework of the relationship between teachers and curriculum materials for this study. The next chapter discusses the methodological framework that guided the collection and analysis of data.

CHAPTER 3

METHODOLOGY

This study examined teachers' instruction-related experiences when using new inquiry-based curriculum material. The study focused on the teachers' teaching activities related to using *Clinical Clark*, an interactive case study whose development by a UGA research team was described earlier. In this chapter, I describe the epistemological stance guiding this study. Then, I present an overview of the research design and a thorough description of the research participants and the research context, including a description of the instructional context of each teacher and the case study that the teachers used in class for this study. Finally, I illustrate the sources of data and finally the methods used in the collection and analysis of data.

Epistemological Stance and Application to Research

All research is guided by basic belief systems based on ontological, epistemological, and methodological assumptions (Guba & Lincoln, 1994). These assumptions, in turn, inform the methodology of a research study and shape the interpretation of findings. As Crotty (1998) explained, our epistemology "has crucial things to say to us about many dimensions of the research task. It speaks to us about the way in which we do research. It speaks to us about how we should view its data. We will do well to listen" (p. 65).

Considering how I make assumptions about the making of meaning, I placed myself within the standpoint of constructivism. Constructivism begins with the premise that the human world is different from the natural world. The human world, therefore, must be studied differently (Guba and Lincoln, 1990). Guba and Lincoln (1989) included among the primary assumptions of constructivism the following:

- "Truth" is a matter of consensus among informed and sophisticated constructors, not of correspondence with objective reality
- "Fact" has no meaning except within some value framework, hence there cannot be an "objective" assessment of any proposition
- "Causes" and effects do not exist except by imputation….
- Phenomena can only be understood within the context in which they are studied; findings from one context cannot be generalized to another; neither problems nor solutions can be generalized from one setting to another….
- Data derived from constructivist inquiry have neither special status nor legitimation; they represent simply another construction to be taken into account in the move toward consensus. (p.44-45)

Constructivism stresses the importance of examining prior knowledge and prior experiences. All people come to new situations with knowledge, skills, expectations, memories, and misconceptions with which they try to make sense of their experiences (Clark, 1998). According to Marlowe and Page (1998), our prior experiences, knowledge, and learning affect how we view new experiences and learning. In turn, our interpretations affect how we construct knowledge and define this new learning.

According to constructivism, the knowledge about teaching that is constructed by teachers builds on their school-related prior knowledge. Most teachers have had many experiences in schools and classrooms since they entered a teacher preparation program. They have participated in and observed many aspects of the school culture, including the behavior of their teachers (Powell, 2000). These experiences and observations influence the teachers' perspective and practices in the classroom. In particular, exposing teachers to new curriculum materials may allow them to examine their own perceptions and classroom situations from different perspectives. When teachers implement new curriculum materials, they will be engaging with a classroom reality and making sense of it.

Constructivism influences my interpretation as a researcher about how the participating teachers constructed their own meaning about their students as well as their teaching practice in the classroom when they use the new curriculum material. My interpretations are a constructive process in a sense that they were also based on the constructed meanings that the individual teachers made of their own experiences. Thus throughout this study my decisions and interpretations have consistently been a product of the epistemological stance of constructivism.

Research Design

Interpretive research was employed in exploring science teachers' instructional experience with the 3-D animation-based case study. Tobin (2000) asserted that interpretive research is a good way to understand a community in terms of actions and interactions and in terms of the participants' own perspectives. Tobin further claims that the advantage of employing an interpretive study is its flexibility and emergent nature. Nevertheless, the primary focus of interpretive research is to gain a clear picture of the central tendencies (patterns) and also of the phenomena that tend to deviate from those central tendencies (Tobin, 2000).

The individual is the focus of interpretive research. Cohen, Manion and Morrison (2007) asserted that individual actions are meaningful if researchers ascertain the intentions of the actors and understand how these actors make sense of their experiences. Cohen, Manion and Morrison (2007) further described interpretive research design as a perspective that "gives way to multifaceted images of human behavior as varied as the situations and contexts supporting them" (p. 22). As used in educational research, interpretive perspectives presume that teaching is a highly complex, context-specific, interactive activity that values differences across classrooms, schools, and communities. Cochran-Smith and Lytle (1990) further claimed that interpretive research provides detailed, descriptive accounts of complex school and classroom events that allow researchers to fully understand the meanings these events hold for the participants involved.

Specifically, the case study approach was chosen to examine teachers' experiences with the 3-D animation-based module. This approach provided an excellent opportunity for me to examine the thoughts and actions of teachers with regard to the uses of specific curriculum material. Yin (1994) defined a case study as an "empirical inquiry that investigates a contemporary phenomenon within its real-life context" (p. 13). This characterization stresses the contextualized approach to evaluating people, events, and things. It involves a close examination of people, programs or issues for purposes of illumination and understanding (Hays, 2004). Therefore, the case study approach was well suited to make reasonable interpretations about the science teachers' experience with 3-D animation curriculum materials based on their verbal expressions.

Participants

The participants for this study were six high school science teachers and two student teachers. Three of the participants had used the beta version of the case study called *Clark* in the spring semester, 2010, and all the six teachers had used the animation called *Clinical Clark* in the fall semester, 2010 or the spring semester, 2011. One of two student teachers co-taught the classes with her mentor teacher; the other one taught the classes by herself. Two of the participants work at the same high school, which is a private school. Four of the teachers were experienced teachers who each had accumulated more than fifteen years' teaching experience and other two had five or six years' classroom teaching experience, respectively. Table 3 presents background information about the participants. For confidentiality, all were given pseudonyms.

Table 3

Background Information of Participants

Name	Ethnicity/ Age/ Gender	Education	Teaching Years at the time of study	Teaching Subject at the time of study
Mr. Watts	European-American/ 60s/ Male	B.S.	37 years	Honors Biology/ AP Biology
Ms. Thorn	European-American/ 30s/ Female	B.S. M.S. Ph.D.	7 years	Introductory Biology/ Honors Anatomy/ Physiology
Mr. Lennon	African-American/ 30s/	B.S. M.A.	17 years	Biology/ Zoology

	Male			
Ms. Franklin	European-American/ 50s/ Female	B.S.	19 years	Biology/ Botany
Mr. Palmer	European-American/ 30s/ Male	B.S.	9 years	Biology/ Honors Biology
Mr. Hall	Caucasian/ 30s/ Male	B.S. M.Ed.	6 years	Inclusion Biology/ Biology/ AP Biology
Ms. Mitchell	European-American/ 20s/ Female	B.S. Process in M.Ed	Student Teacher (Mentor: Ms. Thorn)	Biology
Ms. Rhodes	European-American/ 20s/ Female	B.S. Process in M.Ed	Student Teacher (Mentor: Mr. Hall)	Inclusion Biology Biology

Mr. Watt

In addition to his 37 years of teaching experience, Mr. Watt has a Bachelor of Science degree in Botany and M.Ed. degree in Science Education. He taught science at a private school in north Georgia for his first three years of teaching, and he has been at his current school for thirty-four years and has taught physics, chemistry, physical science, biology, and AP biology. He was teaching Honors Biology and AP Biology at the time of the study and was involved in developing the interactive case studies, so he was very familiar with the materials. He had used the beta version of *Clark* with his AP Biology students in spring 2010 and he used *Clinical Clark* with his Honors Biology students. He was convinced that curricular materials such as this could be significantly beneficial additions to the biology curriculum so he wanted to support and participate in the development of the innovative software.

Every fall, his Honors Biology students use a piece of software called *Mage* which is free on the Internet and is used to visualize the 3-D structure of proteins. In a study, he conducted a few years ago, which was published in *The American Biology Teacher* magazine, the use of the *Mage* program allowed the students to not only enjoy the unit more, but also to retain a lot more of the big ideas about protein structure than the control group, and even a surprising amount of minutia, almost seven months later.

Ms. Thorn.

In addition to having 7 years of teaching experience most of which occurred in a private school (the same school as Mr. Watt), she has a bachelor's degree in biology, a master's degree in science education, and a Ph.D. in science education. She has taught physical science, principles of technology, anatomy and physiology, and biology. She was working with a student teacher named Ms. Mitchell. Ms. Thorn was teaching three sections of introductory biology at the time of the study. She taught the first section and the student teacher taught the other two sections of biology for this study. The students' answers after using *Clinical Clark* were graded by Ms. Mitchell.

Mr. Lennon.

With 17 years teaching experience, Mr. Lennon was teaching zoology and biology at the time of the study. He used the beta version of *Clark* in his biology class in spring 2010, and he used *Clinical Clark* in zoology in spring 2011. The zoology class was a new course in his school. Working without a textbook, he used many scenarios and problems for the students in his zoology class to solve. He has a bachelor of science in biology and a masters degree in educational leadership. Although he grew up in a family of teachers and his mother encouraged him to teach, he wanted to be a lab technician. However, he took courses for teacher certification at college as well because his mother kept saying he needed to have a plan B. Teaching was not what he intended to do, but he ended up making teaching his career. Even though teaching was not the plan he originally made, when I observed his classes, I felt he just loves teaching science and talking with his students and the many activities he used were designed to keep his students actively involved.

Ms. Franklin.

With 19 years of teaching experience in a high school, Ms. Franklin taught regular biology and botany classes during the fall semester of the study. She used *Clinical Clark* in three sections of her regular biology class. She has been active in a variety of professional development activities during her career. In one of these activities she participated in a trip to Costa Rica and found that the ecological knowledge gained has been a great addition to her teaching. She works closely with university science teacher education programs and is often the cooperating teacher for student teachers. She is also a strong proponent of secondary science teacher education that is conducted as site-based programs.

Mr. Palmer.

In his 9 years of teaching experience in three high schools, Mr. Palmer had taught physical science, biology, and tools for success, and he used *Clinical Clark* in his honors biology class. He has both bachelor’s and master’s degrees in science education. At the time of the study, he was an active coach working with multiple men’s sports at his school. He characterized himself like this, “I am a strange bird, I play around with the kids a lot and joke around with them and try to keep it kind of fun. … I tend to do different things off the wall. I try to keep them on their toes.”

Mr. Hall.

The head of department for 5 years, Mr. Hall taught all levels of biology, inclusion, regular, honors as well as AP biology for 6 years at a high school. He used *Clinical Clark* in his inclusion biology and regular biology classes. He has a bachelor’s of science degree in biology and M.Ed in science education. Prior to his undergraduate college experience he had always lived near the ocean and was drawn to science. He had a great high school biology teacher who made him concentrated on science research. Consequently, he went into college to pursue a degree in marine biology and in particular to use marine biology as a means to search among the biota of the ocean to find a cure for cancer. He was a very diligent college student and graduated summa cum laude in the department of biology. He had study groups and he found he liked working with people much more than working at the lab bench. Then, in the last semester of his undergraduate degree, he took an internship in which he co-taught an undergraduate biology lab section with graduate students. He loved working with the people and sharing his enthusiasm, and he found it was rewarding. This resulted in him pursuing an M.Ed degree in science education. He said, “It’s really my love for working with young people and this passion for science, and I found that this career allows me to do both those things and utilize both of those thing that I love so much.”

Ms. Mitchell.

At the time of data collection, Ms. Mitchell was Ms. Thorn’s student teacher. She has a bachelor’s degree in biology and a master’s degree in poultry science. She started the student teacher program for science education in the fall of 2010. She did a practicum, just observing mentors at a high school and taking courses at the university in the previous semester. Working inside in Ms. Thorn’s classroom, Ms. Mitchell taught two sections of the three introductory biology classes as a part of her internship. She observed how Ms. Thorn taught the class with *Clinical Clark* in the first section and then she taught the second and third sections by herself. However, she graded all the students’ responses from three sections due to Ms. Thorn’s maternity leave two weeks after the classes.

Ms. Rhodes.

Ms. Rhodes was Mr. Hall’s student teacher. She earned a bachelor of science degree in forest resources in 2010, and was working toward a master’s degree in science education during the study. She likes working with people outside in nature and with science content in the classroom, and that was her motivation for becoming a teacher. She was teaching regular biology and inclusion biology under Mr. Hall’s guidance. She was in charge of the classes using *Clinical Clark* so mostly she led the instruction or class discussion during the classes. However, Mr. Hall actively discussed with individual students while other students were working with *Clinical Clark*.

Research Context

The instructional tool participants implemented in their classes.

This study was conducted as part of a project to create highly realistic interactive animations supported by the National Institutes of Health Grant (1R25RR025061). The first goal of the project was to help students' construction of knowledge in science through inquiry. The second goal was to fulfill teachers' needs for an inquiry activity with dynamic visual images that represent living biological processes.

The project team consisted of experts from various specialty fields within the academic community of the University of Georgia, and the team attempted to design these materials as instructional aids for both teachers and students. The interdisciplinary team was tasked with designing all aspects of the new inquiry-based curriculum: writing scripts, ensuring the scientific content was accurate, shooting video footage, creating original background sounds, and designing and programming the computer interface.

One characteristic of the new materials was that the team aimed for interactive 3-D models and environments in which students could explore and interact, rather than simply watching animations made and presented in the form of movies. The team has developed 3-D models of the structures involved in basic biological processes that had been identified as being important for all high school students to understand – osmosis, diffusion, and filtration and has incorporated these models into a video game engine (Unity) that allows the students to move around in the environment.

Each of the new curriculum materials was based upon a case study involving an animal or human that has been altered by a specific disease state related to the biological processes. *Case study* is a teaching approach commonly used in high school science classes as an inquiry activity. (Thus a curricular case study is different from a research methodology case study, which is a detailed contextual analysis of a limited number of events or conditions and their relationships.) In the curricular case study approach, students are given a scenario about a situation with a particular problem, and their goal is to determine what the underlying cause of the problem is, using other resources if they need them to solve the problem.

Clinical Clark

At the time of the study, the curriculum module related to osmosis was ready to try out, while the other two were waiting for their beta versions to be tested in classrooms. For this study, the participant teachers used the curriculum materials called *Clinical Clark* related to osmosis in their classes.

Clark is a Holstein calf, lying on its side shaking from seizures. It is up to the students to make the correct diagnosis about the cause of the seizures in order to choose the treatment that will cure the problem. Using 3-D computer models created by a team of animators, the students are able to zoom in to examine the calf's brain and monitor the flow of water particles in and out of the capillaries of the brain. After answering a series of questions, the students make a diagnosis, proceed with a treatment and then if correct, see a happy, healthy calf on its feet again. If incorrect, the calf becomes sicker, and students are prompted to re-examine their data to arrive at the correct diagnosis.

Following is an outline of the procedure of the program:

1. The student enters his or her name and logs in when the program starts running.
2. The Patient Record slides out from the left hand side of the screen and has clickable tabs on its right hand side.

3. In the Symptoms page, the student is given the clinical symptoms and an embedded video plays showing Clark having seizures.
4. Students "fly into" and explore Clark's brain where they have access to a data panel and clickable "function" icons (explore, measure, information, zoom, and treatment) and also a "Clark Cam" where they can see how Clark is doing at any point.
5. Students use the "measure" tool to capture data from the blood, matrix and neurons.
6. Having taken measurements within the brain, the student’s data are uploaded into the Patient Record where they are interpreted by the students.
7. The student’s level of understanding is then assessed as questions are answered.
8. Once they have collected and interpreted the data, they then decide upon a diagnosis, using what they have learned about osmosis, and are provided with three possible treatments. They must predict which treatment will work best, justify their decision in the form of a hypothesis, and then test that hypothesis by administering the treatment to Clark and monitoring the values in the data panel that changes dynamically over time. If the student’s choice is correct, Clark gets better, but if the treatment is contra-indicated, Clark’s condition worsens.
9. Finally, the students write a “case study report” where they must include details of how they came to their hypothesis, how they tested their hypothesis and where osmosis was involved in both the cause and remedy of Clark's condition.

In spring 2010, the Beta version of *Clark* was available, and five teachers including two teachers who participated in the developing process, used this version in their classrooms. The Beta version animation differed from subsequent versions primarily because the student work directions were given to the students as a written material about a sick calf. When the teachers used the beta version in their classes, three to five members of the project team were present to see how well the program functioned. The main purpose of this tryout was to identify errors that the development team had not experienced and to obtain feedback from students and teachers in order to make the program better before trying it out with a larger population.

Based on the results from the first year's tryout, the student worksheet was intergrade into the next version of the case study, which called *Clinical Clark*. All the information and questions in the student worksheet given to users in the beta version were transferred into an interactive lab notebook that included the patient record, symptoms, treatment, treatment summary, and case summary. The biggest improvements were in the interface that the student uses to go through the program. In *Clinical Clark*, the development team was able include components of the program that would help guide the students to think through the problem and figure out the correct procedure for treatment. For example, if the students did not write any words in the text box, they could not go to the next step. If they had the sequence of events that lead to the development of seizures of Clark's response to the treatment of choice, then the students had to reorder these events until they were correct. In *Clinical Clark*, a student's responses were saved as an html file with the name which the student entered on the first page of the program. By examining the html files, the teacher can easily check each student's answers. When the teachers used *Clinical Clark* in class, the development team was not present.

Teachers were given a flash drive that contained the program, instructions for running the program, and how the material covered in the case study relates to NSTA standards and Georgia Performance Standards. All the Word documents and PDF files provided to teachers are included in Appendix A.

Instructional Context

The school environments related to technology varied, although five of the six schools were public schools in northeast Georgia. The private school was a laptop school (i.e., every student has a laptop computer). The school's students lease laptops from the school and each computer comes with a common hardware structure and software suite so that they can exploit this technology in their curriculum. The science departments of two other participating schools have carts of laptops that the teachers in those schools can check out so the students can do the activity in the classroom. The other two teachers signed up for the computer lab, and they did the classes there. The two remaining schools had no specific computer lab for science classes in school. As a result, the teachers in those two schools asked students to go to other classrooms, such as business or technology classrooms that have computers, or to the media center. One school had an unusual system of computers in the computer lab. The stations in the computer lab were networked in clusters of 3-5 computers to one shared CPU, and the program was thus fully functional on only 10 of the computers within the lab.

With a flash drive and teacher materials the teachers could become acquainted with the material and coordinated adding the program to their school's computers and server before they used the materials. Three teachers had trouble getting the program on an easy to access network due to security blocks at their schools. Therefore, they loaded the program on each computer at the beginning of their classes. Two teachers in the private school and two teachers in two public schools uploaded the program to their school network and let the students load the program on their laptops. If it took too long to load the program from the school network or if the program crashed while the students were working, the teacher loaded the program on the computer by the flash drive. Table 4 presents information about the class context. For confidentiality, all schools were given pseudonyms.

Table 4

Information Regarding Instructional Context

School	Participant Teacher	Class		The Place
		Subject	Number of Students per Class	
Adams Academy	Mr. Watt	Honors Biology	15/15/15	In classroom, Each student has laptop
	Ms. Thorn, Ms. Mitchell	Biology	5/16/11	
Clinton County High School	Ms. Franklin	Biology	14/21/23	Computer lab
Washington High School	Mr. Lennon	Zoology	15	Media Center, Business Classroom
Lincoln High School	Mr. Palmer	Honors Biology	26	In classroom Laptop
Kennedy High School	Mr. Hall, Ms. Rhodes	Inclusion Biology Biology	24 12	Computer lab, Networked computers

Data Collection

To understand the experiences of the teachers in this study, I collected the data from multiple sources, including classroom observations, semi-structured interviews, lesson plans, teachers' written reflections (emails to researcher), students' response samples, and field notes. Classroom observations were an important data source for the study. I observed each participant's classroom when they used the beta version of Clark or *Clinical Clark*. I wrote field notes at the time of observation. Through direct observations, I was better able to understand and capture the context within which teachers and students interact and how teachers dealt with the new technology curriculum material. At certain times during the research, a second researcher was present and served as a classroom observer; his field notes provided an additional source of data.

Interviews with each participant were another primary source of data. I employed semi-structured interviews through which the interviewees were able to tell "their own stories" in their own words. This approach allowed me to move beyond my own experiences and ideas and to really understand the teachers' points of view. That is, I used pre-established questions as well as follow-up questions and probes to clarify responses or to obtain additional information. The format of the interviews was relaxed, spontaneous, and open-ended. All the interviews were audio-taped and transcribed. After recruiting participant teachers, the second researcher and I visited each school for an introductory meeting with each participant. In the initial meeting, we handed the program to the teacher and gave the brief introduction and demonstration of the program. The second researcher was present during the interviews and occasionally asked a question. We discussed the school computer settings and got information about the classes in which the teacher planned to use the program. Then a pre-interview was conducted a few days before using new curriculum material. The pre-interview concerned the teachers' backgrounds, their orientations to science teaching, and their planning for the class they were teaching. It was conducted before observing the class work through the case study. After observing the class, I interviewed the teachers about the teachers' overall reflections on the class, their students' learning through the class, and their plans with *Clinical Clark* in the future. The post interview was conducted immediately after class and/or in the subsequent days, depending on the teacher's schedule.

In addition, email communications I had with the participants were used as data. During the post interview, with regard to the unit including the lesson using the program, the teachers shared their lesson plans, the materials that they used in the unit, and the students' answers from the program. In the following section, I explained in detail how and when I gathered the above data sources through the project and the purpose of each data source.

Procedure of Data Collection

The time of data collection was divided into two periods according to the procedure of the collection of data and the version of the case study. In spring 2010, when the beta version of *Clark* was available, three teachers on the development team wanted to try the program with their students and invite the project team to their classes. Also, three other teachers recruited by a member of the development team were willing to try the beta version of *Clark* in their classes. During the classes, the teachers as well as the development team members observed how the students reacted to doing the animation. The development team members actively interacted with the students to help the students understand what the team wanted students to learn from the experience. Furthermore, the development team sometimes introduced the project to students in the beginning of the class, and they debriefed the students about the activity at the end of class.

I was one of the team attending and observing the classes. Regarding the study of how teachers think about using technology-based curriculum materials, I conducted interviews with the teachers after they used the beta version of *Clark*. At that time, the primary purpose of the observation of class was not to know how teachers implemented the program in a real class but to determine how well the program functioned with students and teachers in real classrooms. Therefore, for this study, I did not include the observation as a data source. The interview data were analyzed, in terms of teachers' perspectives relating to the use of new technology curriculum material. The questions used in the interview are included in Appendix B.

For five or six months after the initial tryouts in spring of 2010, the development team modified the original Clark module into *Clinical Clark*. The primary change was the integration of the student worksheet into the software as described earlier. In winter 2010, we emailed several local high school biology teachers to introduce *Clinical Clark* and to ask if they were interested in using this in their class. Three teachers were excited about using the program and were willing to use the program in spring 2011. Three of the teachers who had used the beta version of Clark in spring 2010 also wanted to use *Clinical Clark* in spring 2011. Two other teachers were not teaching biology in spring 2011, and so were not available to participate. For *Clinical Clark*, three teachers who were entirely new to the curriculum module and three who were experienced with the beta version participated in this study. Throughout this time, all the teaching environments in class were preserved and nobody interrupted the class period. I was the person from outside as a non-participant observer in class. At certain times during the research, the second researcher was also present in the classrooms and served as a classroom observer, as mentioned previously. In addition to the classroom observations, the teachers were interviewed at least twice, once or twice before and once or twice after using the program in class. The questions used in the interviews are listed in Appendix B.

The entire observation and interview procedure with each participant is summarized in the table in Appendix C. The table includes the date each observation or interview was conducted, and what kinds of data were collected on that date.

Data Analysis

An overview of the procedures of data analysis

This study was approached using the phenomenological framework. Phenomenology assumes that each phenomenon has an essence that is universal to human experience, and also that tradition or culture overlies the essence, so we need to be critical of inherited and prevailing meanings. Thus, inquiry from a phenomenological perspective asks questions such as “Is this what the experience is really like?” or “What is the structure and essence of the experience of this phenomenon for these people?” (Van Manen, 1990, p.99). In other words, phenomenological inquiry systematically attempts to uncover the internal meaning structure of lived experiences. Consequently, it involves understanding certain phenomena from the actor’s own perspective by approaching it in as open a manner as possible. Accordingly, this research attempted to understand teachers’ experience with new curriculum materials from the teachers’ own perspectives, not from the researcher’s pre-conceived notions.

The analytic techniques chosen for this research were the integration of inductive analysis with the interpretive constructivism and the constant comparison method. The purpose of inductive analysis is to “discover important patterns, themes, and interrelationships” in order to understand the meanings that exist in the phenomenon being investigated (Patton, 2002, p.41).

During the analysis, I allowed the research findings to emerge from the frequent, dominant, and significant themes inherent in raw data without the restraints imposed by research or a particular theory.

The first step of the analysis was to determine how teachers experience the target phenomena. First, the audio-taped interviews were transcribed verbatim. Each transcript was read thoroughly, and all responses relevant to the phenomena of interest were noted on the transcript. As suggested by Coffey and Atkinson (1996), I read and reread the transcripts several times in order to reflect the participants' answers accurately. When events or beliefs were found to be similar in nature, they were grouped under broader and more abstract categories (Bogdan & Biklen, 2007; Strauss & Corbin, 1990). These categories were formulated into meanings, and the meanings were clustered into themes. In this process, the codes, words, or phrases that emerged directly from the transcripts were used in order to stay as close to the original transcripts as possible. As LeCompte and Preissle (1993) stated that the codes systematically organize and reduce the original data set, so the researcher can manage and retrieve meanings from the transcripts. After the codes were constructed, the data were examined for patterns across all participants. I gradually modified and refined the preliminary categories through the analysis process. Along with analyzing the data, I concurrently made interpretations. According to Patton (2002), interpretation is the researcher's effort to make sense of the data using his or her own experience, perception, and intuition. In other words, the researcher's interpretive framework determines the way to impose meaning on the data. Thus, as Wolcott (1994) stated, it is important to provide neither too much unwarranted personal opinion, nor too little truly insightful commentary.

Summary

In this chapter, I have provided a description of the methodological framework which guides the study. Situating myself in an interpretive constructivist standpoint, I discussed the rationale for using a qualitative case study approach in order to examine teachers' experiences with the 3-D inquiry-based module. Then, I presented a thorough description of the research participants and the research context, including a description of the instructional context of each teacher and the 3-D inquiry-based module that the teachers used in class for this study. Finally, I described the procedures for collecting and analyzing data and the processes for effectively managing data analysis.

CHAPTER 4

FINDINGS

The purpose of this research was to examine science teachers' instructional experiences when using novel curricular materials that included 3-D models and animations of biological processes. The study focused on the teachers' instructional activities while they were using *Clinical Clark*, which was developed by a UGA research team as described in Chapter 3. This chapter aims to present the findings that were gleaned from the analysis of the data collected. I address the findings according to three identifiable stages within the teaching process. These stages were labeled pre-active, interactive, and post-active by Jackson (1968). In the examination of the first stage, I describe the participant teachers' planning decisions, focusing on their previous teaching experience with the subject matter content and the unit, their general perspectives of teaching science, and the rationale they gave for the selections of specific materials and activities. In the section on interactive stage, I present the teachers' decisions while implementing the curriculum materials. This section will include observations of the classrooms sessions in which the instruction took place. In the section that examines the post active stage, I analyze the teachers' reflections on the lessons that included the content and module related to *Clinical Clark* in the days after the instructional session or sessions.

Pre-active: Lesson Planning

In this section, I address the teachers' instruction-related planning decisions during the pre-active stage. The pre-active stage was earlier defined as the time before teaching, when instruction-related activities that are preparatory for teaching are made. The findings that comprise this section arose from the analysis of data collected during the pre-interviews. These interviews were aimed at collecting data related to two subcomponents of the research questions. These are:

1. What factors influence teachers' decision-making about the use of the new curriculum materials prior to their in-class implementation of the materials?
2. What characteristics of the *Clinical Clark* module were considered important to the teachers as they planned to use the materials within an instructional unit (cell unit) in which osmosis was taught?

To identify factors that influenced the teachers' planning processes for using the new curriculum materials, each participant teacher's pre-interview was analyzed using cross case analysis. From that analysis an explanation was developed to fit each of the individual teachers. This analysis led to identification of themes that were used to conceptualize the data from all the cases (Merriam, 1998). During the cross-case analysis, I looked for identifying characteristics that denoted similarities among the cases. Once these initial characteristics were identified, I examined the data again, looking across the cases to distinguish differences or anything that stood out as unique to a particular case. The findings are reported under the following headings: (1) instructional experiences with the unit; (2) perceptions of using technology-based curriculum material; (3) teachers' views of science and science teaching; and (4) rationale for using or not using specific materials.

Table 5

Samples of the Interview Questions related to the Pre-Active Stage

Interview Questions
• Tell me about your science teaching experience (follow up: number of years, subjects taught, etc).
• Could you describe what your science classes look like? What are the characteristics of your science teaching?
• Tell me how you plan for a lesson
• How did you teach the concept of osmosis before?
• What types of technologies have you used for class?
• How do you use the computers for your class?

Instructional experiences with the unit

Teachers use curriculum materials differently at different stages in their careers. Teachers who lack experience may use new materials willingly (Behm & Lloyd, 2009; Christou, Menon, & Philippou, 2009), whereas those teachers with a great deal of experience with specific types of curricula may resist using tasks from a newer, standards-based curriculum (Collopy, 2003). Teaching experience and an extensive understanding of pedagogy improve one's ability to plan lessons that use a variety of materials and better meet the needs of one's students (Behm & Lloyd, 2009). The teachers' prior instructional experiences with the subject matter content in a given unit affects their decision making in the pre-active stage of teaching from the initial decisions about use of the curriculum materials to planning the overall lesson.

To examine how this decision-making shift occurred among the teachers who used *Clinical Clark*, I conducted an initial pre- interview. In this pre-interview, I hoped to learn how the teachers had taught the subject matter content in their previous teaching experience. Specifically, during the pre- interviews, all the participant teachers were asked a set of questions aimed at discerning how they had previously taught the topic of osmosis within any curricular units or courses.

Not surprisingly, each of the teachers reported that they had taught osmosis as the part of a unit that was primarily focused on "the Cell." Although there are minor variations among the participating teachers, the teachers addressed osmosis as an inherent content theme related to the structure and function of cell. When the teachers described the lesson flow they used to teach about osmosis, some of the consistencies between the teachers can be captured in the form of "instructional sequence statements." For instance, after discussing cell organelles, each of the teachers then reported that they shifted the focus of their instruction to the cell membrane. Another example dealt with cell structure, which for these teachers meant analyzing the chemical structure of the phospholipid bilayer and fluid mosaic model. The teachers consistently reported that after they had concluded that the students understood cell structure, the students also began to realize how the cell membrane is able to regulate the movement of entering and exiting molecules to maintain homeostasis. The teachers discussed the types of molecules that will easily cross through the membrane, the types of molecules that cannot do this, and those that will need some type of protein to help them move across or to actively pump the molecule in/out. In the midst of that discussion, the teachers included osmosis as movement of water. Mr. Watt described his previous teaching of osmosis:

> It’s an entire chapter of diffusion, osmosis, active transport, and so forth, but in the other freshmen book it’s one third of the chapter, and so I introduced them to diffusion... the processes that moves stuff through membranes, and we talk about what is diffusion, what is osmosis, what controls those things, you know, we talk about a lot of concentration gradients, and I tried, I expand their vocabulary to just using terms like hypertonic, and hypotonic, isotonic, and then once I have them making accurate predictions about what a cell will do in different concentrations of solution, then we move to moving solutes, dialysate, moving solutes through the membrane and that involves symports, uniports, antiports, and active transport and the kinds of membrane transport proteins and how they function in the cell membrane the different kinds, and then we finish talking about active transport, the moving in the opposite direction from diffusion, the opposite direction from facilitated diffusion by using ATP and how, we don’t actually use ATP to pump every sugar molecule that sort of thing. (Mr. Watt, Interview #1)

Primarily the teachers reported that they employed a teacher-centered instructional strategy when teaching about concentration gradients as well as discussing the types of molecules that are able or unable to pass through the membrane. At first the teachers explained the concept of diffusion as one among several types of molecule movements—diffusion, osmosis, facilitated diffusion, and active transport. They explained the concept of diffusion as a related phenomenon by using a physical demonstration such as releasing a fragrance from a bottle in the front of the classroom. Then, the teachers brought up the concept of osmosis comparing it to diffusion. Ms. Thorn explained her teaching experience of diffusion and osmosis:

> I typically teach diffusion and osmosis together; one of those involves movement of solute, and the other one involves movement of solvent and so they just have figured out

> diffusion and they are real excited about that, and then you started talking about, okay, what about when the solute can't move, what happens? And the solvent moves so they tend to get confused, but I usually put a big beaker up on the board and we drop, we draw a semi-permeable membrane, and we talk about osmosis. (Ms. Thorn, Interview #1)

At that point, the teachers reported that they introduced to the students the vocabulary related to tonicity like hypertonic, hypotonic, and isotonic. When they taught the concept of osmosis and the movement of water according to concentration gradients, all of the teachers reported that they drew graphic organizers on their classroom whiteboards or showed graphic organizers that they had as a component of a PowerPoint presentation. In the graphic organizers, they drew arrows indicating water movement through the semi-permeable membrane from hypotonic to hypertonic until the solutions on both sides of the beaker are isotonic. Two teachers, Mr. Watt and Mr. Hall, said they showed a video clip that they found online showing the movement of fluid through a semipermeable membrane from a solution with a low solute concentration to a solution with a higher solute concentration until there is an equal concentration of fluid on both sides of the membrane. Later in the instructional sequence the teachers engaged in more teacher-entered talk about facilitated diffusion and active transport, which needed transport proteins in order to successfully move molecules or ions through the membrane.

In teaching osmosis, five of the teachers stated that they had led one or two hands-on investigations about osmosis. The most popular activity that the teachers had done with students in the past was either the egg or potato lab. These laboratory activities were intended to teach how osmosis impacted tissues using either an egg from which the shell had been removed or a potato slice that was immersed in solutions of different salinities. The teachers wanted the students to understand biological changes that occur to an egg or potato tissues over a period of time in different solutions and to relate these changes to the phenomenon of osmosis. In the egg lab, students put an egg in hypertonic, isotonic, and hypotonic solutions and then made visual observations of how it swelled or shrunk. For the potato lab, the teachers had students test samples of potato tissue to see how much water they absorb or release in salt solutions of varying concentrations. The students placed the pieces of a potato into solutions with different concentrations of solute such as salt or sucrose, and then they recorded how much the rigidity of the potato slices changed. Following this, the students measured the mass changes; then they graphed that and predicted what the concentrations of water were in the potato cells before they put them into those solutions. In the academic year prior to this study, four of the six teachers did the egg lab, one did the potato lab, and the other one decided not to use any the lab activity related to osmosis due to lack of time; in previous year that teacher used an egg lab.

An examination of the instructional strategies described in the interviews about the teachers' prior instructional experience with the unit of osmosis indicated they used teacher-centered lectures when they first taught both the concept of osmosis and the vocabulary related to tonicity. Ms. Thorn described how she taught the vocabulary related to tonicity:

> I did a drawing and explained the differences between hypertonic and hypotonic, and which way would water move and I am very picky about the terminology. Because we can't talk about tonicity by itself. So, we can't look at the cup of tea and go, that tea is hypertonic, you know, you can only talk about it in relation to another solution and they did pretty well. (Ms. Thorn, Interview #1)

In describing their past instruction about osmosis, each of the teachers discussed their emphasis on lab activities. They mentioned that they usually included an osmosis-related lab after lecturing on osmosis. Each of the teachers had provided students with an example of osmosis to illustrate for the students the role of osmosis in living tissues like an egg or potato. However, one participant teacher, who skipped the laboratory activity in the previous year, also indicated that the laboratory activity could be optional, when time did not allow. The participants in this study brought many years of experience to teaching osmosis— two teachers had six or seven years teaching experience and the other teachers had over 15 years. Consequently, over the years they accumulated a variety of experiences with regard to different instructional approaches to teaching osmosis. As a result, they developed their own protocols for the unit of osmosis: first, they would do a lecture on osmosis, and then they would select one of the activities they described above (for example, the egg lab or the potato lab). In their discussion about their prior experience in teaching osmosis, I could not find any evidence that they planned to change their instructional strategy about osmosis or that they felt they needed other resources that could be used in class. Thus *Clinical Clark* was not filling a gap in their instruction. Rather, the teachers seemed to regard *Clinical Clark* as a new way of teaching osmosis, a topic with which they were already very familiar. And after becoming familiar, even in a superficial sense, with the *Clinical Clark* module, each teacher expressed a desire to try a new way of teaching osmosis using the module. The features of the module that made them think it was worth a try will be discussed in detail in the last section, along with the rationale for using or not using specific materials.

Above all else, based on their former students' performance on state and school tests, the teachers believed that their students needed additional support to learn about the terminology related to tonicity and thus were immediately open to using the *Clinical Clark* module because of its emphasis simply on this terminology. In other words, the teachers' osmosis-related instructional experiences contributed to their perceptions of students' understandings and shortcomings when learning osmosis. Based on my analysis of the teachers' interviews, it was this perception that made them amenable to using *Clinical Clark.*

Teachers' views of science and science teaching.

The teachers' philosophy of science and science teaching primarily affected their design of an instructional plan that took place before instruction. One of the most important factors contributing to a teacher's use of curriculum materials is the degree to which a particular curricular material fits the teacher's beliefs about science, pedagogy, and science teaching and learning. Following are teachers' comments from the interviews regarding their thoughts about science and science teaching.

Both Mr. Palmer and Mr. Watt believe that science is abstract. Much of the content, in Mr. Palmer's view, is hard for students to grasp. This is especially true of biology. Mr. Palmer described his viewpoint in the following ways:

> When you are talking about the cells and [the cells are] so small, they can't really, you know, they can see some of stuff in microscope and all, but a lot of them have a hard time really grasping how atoms, groups of atoms come together to form cells and groups of cells form tissues and everything. It's hard for them to really understand and grasp because it's abstract for them. (Mr. Palmer, interview #1)

Mr. Watt also pointed to his belief that biology is abstract to teach. He emphasized the importance of visualization in science teaching.

> Concepts of molecules, um, chemical reactions things like that, are things that children cannot see. Much of the biology below the cellular level which is a level I really enjoy teaching… is… involves things that can't be seen. It is a challenge for the teacher to

> come up with various metaphors and drawings and things like that that really stretch our ability [to teach] especially. (Mr. Watt, Interview #1)

Mr. Hall described his teaching style as being very student focused. He said his science teaching is “all over the place,” a variety of different activities, small group, individual, whole class, lab, and hands-on. Mr. Hall believes science is something that you should *do* and not something that you should to “*tell* the kids.” Teaching science, Mr. Hall believes, is about trying to have the students doing science, having them appreciate and understand the nature of science, and determine how what we are talking about today matters to their personal lives. In talking about teaching science, he stated, “great teachers will show you why this matters to your daily life and your future and so my teaching is, it’s kind of couched in that idea that I want to relate to what they already know and show them why it matters to their life now and their future whether they are a science person or not.” (Mr. Hall, Interview #1)

Ms. Thorn, like Mr. Hall, also described her teaching style as being very student focused. As a result, in every unit her classes have at least one investigation where they have to evaluate evidence and support their conclusions.

On the other hand, Mr. Lennon emphasized critical thinking and scientific inquiry in science. He thinks that students should be able to think on their feet about a given situation and should figure out what the problems are and how they can solve them using scientific inquiry and critical thinking. He said,

> The biggest aspect I will look at is to take all of that knowledge they’ve been getting, especially like our seniors, they’ve been getting knowledge all through their school career. Now to apply that knowledge in an actual working form, you know, to actually

> use all these different terms and philosophies and stuff that you learn to actually use it to solve the problem.(Mr. Lennon, Interview #1)

Each of the teachers drew on their views of science and science teaching in their planning decisions. With their views in mind, they looked for classroom activities that supported their view of what it means to understand science. In the planning process, each teacher's view about how science teaching should be conducted was the strongest factor in his/her decisions about selection of curricular materials.

Perceptions of using technology-based curriculum materials

How teachers teach is influenced by several factors including their personality, belief systems, education, teacher training, and teaching experiences. According to Becker (1991), "To create an intellectually rich school environment that incorporates technology, it is necessary to be aware of 'old habits' and 'conventional beliefs' that impede the best intentions to improve schooling through [the implementation of] technology [in instruction] by practicing teachers" (p. 6). In this section, I examine how the participant teachers used technology in their teaching and what they believed technology's role was in teaching and learning.

Technology for this study is defined as hardware related to computers, software applications that run on computers, and the Internet. In addition to the questions mentioned in the previous section, the teachers were asked in the first interview about their use of technology in teaching. Based on their answers, the teachers' use of technology could be divided into two categories according to who uses the technology directly: the teacher or the student. For instance, if the teacher searches for case studies for the students' activity in class and prints it out as a paper handout, the use of the computer and the Internet is a teacher-centered technology. In this study, analysis indicated that the teachers used more teacher-centered technology than student-centered technology.

All the participant teachers reported they usually used the computers as a tool when they made their PowerPoint presentations. They said they searched online to find better animations or pictures than they have previously used in teaching a given topic such as DNA replication or protein synthesis. Also, they said they occasionally find case studies on the Internet and them to let their students work through those case studies.

When I asked how they used technology in their teaching, three teachers, Ms. Franklin, Ms. Thorn, and Mr. Hall, *only* reported those kinds of teacher-centered technology such as using computers and the Internet to search for materials for student to use, which is not for students directly to use the technology. On the other hand, Mr. Palmer, Mr. Watt, and Mr. Lennon were the teachers who had the more varied uses of technology by including student-centered technology even though their most common use of technology was to find and implement teacher-centered technology. In terms of students' use of technology, both Mr. Watt and Mr. Lennon led one or two activities using the computers throughout the semester such as having students go to a website and research a certain science topic. Mr. Palmer said that he put students into class sessions using computers "all the time" in order to aid their practice for the graduation test as well as to do online reviews before the end of course test.

Table 6

Types of Technologies the Teachers Used

Teacher	Teacher-centered technology	Student-centered technology
Mr. Watt	Making PowerPoint	Online Lab
Ms. Thorn	Searching Case studies	None
Mr. Lennon	Finding better animations or	Online Lab
Ms. Franklin	better pictures	None
Mr. Palmer	(All six teachers)	Online review & Preparing Test
Mr. Hall		None

Although the amount of technology used was limited and the type of technology used did not vary, all of these teachers viewed technology as an extra resource for teachers to use. In other words, they saw technology not as an essential part of teaching but as an extra resource, which was good to use, but not indispensable. There appeared to be a general agreement across the teachers that technology is a new and useful way for them to teach what they are already teaching and should be used as much as possible because it is very beneficial. Also, they all agreed it gives the students another way to learn something.

After analyzing the data from these interviews, it is obvious that gaps exist between the teachers' perceptions and practices on using technology during science instruction. The teachers saw the positive effects of technology on teaching and learning science, but the positive perception did not necessarily make them active users of technology. For instance, these teachers know that there are a lot of resources available on the Internet but few teachers spend time looking for new resources using technology. Furthermore, in terms of students' use of technology, when the teachers planned their classes, they were aware of the existence of a lot of resources (student-centered technology), but they tended to plan their classes around methods of teaching they had always used. Yet, in spite of the teachers' low frequency of using student-centered technology in their classrooms, my analysis of the interviews suggests that the teachers did have a positive perception of technology, seeing it as a useful tool in teaching and learning. The teachers regarded that using technology improved the students' interest in doing the activity: "They're being interactive really like you know, the kids in technology today they love to have a lot of interactive things to get involved with it" (Mr. Hall, Interview #1). "They are very comfortable with using the technology and that is the game environment they are so comfortable in and the game itself is fun" (Mr. Watt, Interview #1) This positive perception led the teachers to consider using a new technology curriculum material, *Clinical Clark*, in the planning stage.

Rationale for using or not using specific materials

Shavelson and Stern (1981) identified some important factors— information about students, teachers' attributions of probable causes of student behavior, individual differences between teachers, nature of the instructional task, and instructional constraints— that may affect teachers' pedagogical decisions (see Figure 1 in chapter 2, p. 20). In what follows, I attempt to provide evidence for how Shavelson & Stern's (1981) factors might have influenced the participants' evaluation, selection, and uses of *Clinical Clark*. During the interviews, I asked the general question to each teacher about how they used the different materials available to them when they prepared to teach a unit. In discussing their rationale for evaluation and selection of materials, the teachers referred to their beliefs about teaching, external pressures, prior teaching experience, and perception of their students' abilities and engagement.

First of all, in discussing why they chose to use *Clinical Clark*, the teachers mentioned their beliefs about science and science teaching as one of criteria for their decisions. For instance, Mr. Palmer and Mr. Watt each stated beliefs about how science is abstract. This abstraction is evident in the difficulty students encounter trying to visualize biology at the cellular level. In Mr. Palmer's views, much of the content is difficult for the students to grasp. To help their students, they stated that they tried to give as many examples, representations, and activities as possible. When they were asked the reason for deciding to use *Clinical Clark*, they shared their evaluation of how well the module is visually presented; how much reality is reflected in the module.

The teachers' views, about how science should be taught, also guided their decisions on the selection of curriculum materials. During the interviews, Ms. Thorn and Mr. Hall emphasized that their teaching is very student focused. They stated that they considered what students do and how they perform in class when planning their lessons and selecting curricular materials. Similar to Ms. Thorn and Mr. Hall, Mr. Lennon referred to his views of science and of science teaching when discussing why he chose to use specific instructional materials. Science class, he believed, should be centered on scientific inquiry, scientific investigations, and problem solving. He felt that these activities would increase his students' critical thinking skills. He stated, "A lot of times with teaching I kind of give a problem. One thing that I considered is you actually have the problem and they [students] have to find answers. I wanted them to think more." Also, he emphasized the importance of a real life experience. Whenever he talked about *Clinical Clark* he mentioned this, "Clark it's good because you know, that actually it's almost like a real life experience, you have the calf that's struggling you know, having seizures or whatever, and then actually playing a role of a scientist and figuring out what the problem is."

Students' engagement also influenced teacher's decisions about choosing new curriculum materials. One theme in Mr. Palmer's conversations about instructional materials was the need to make science interesting for his students. In evaluating *Clinical Clark*, he stated, "The 3-D animations are going on, uh, [and these materials] make it kind of fun and exciting for the kids to learn about osmosis, uh, it does kind of make it less abstract they can actually go in 3-D.(Mr. Palmer, interview #1)"

Ms. Thorn identified engagement, both on the part of the students and the teacher, to be the most importance factor for her in making decisions about new curriculum materials. Ms. Thorn believed it doesn't matter how "fabulous" the curriculum materials are if the students aren't paying attention to them. So, she tried to make sure that her students were continuing to be engaged and that they are enjoying coming to class. She considered the whole chapter, asking herself how many different ways the students are able to experience learning related to that specific subject matter. She stated, "The different ways [of teaching this content] make the students keep engaged and then it is going to either reinforce their content, ask them to evaluate evidence for whatever the premise is that their supporting or not." Furthermore, she thought that her own interest with regard to a certain curriculum material is also as important a factor as students' interest. She used to change the instructional materials every year in some units for her own sake. It seems that she was excited to teach with different curriculum materials.

> It's not boring which is the good thing. I think if I taught thirty years and did the same thing, I would be really miserable. So even sometimes if I find a really a good way to do something, I may not do it every year. I may look for another really good way to do it, just keep myself refreshed. (Ms. Thorn, Interview #1)

Like Ms. Thorn, this notion of variety was a common theme in Mr. Hall's conversations about his use of materials. Mr. Hall felt at ease with using a variety of materials in a variety of ways, and he believed it would accomplish his learning goals. However, he did mention two factors that affect the way in which he made plans: the objectives of the lesson and students' engagement.

> How we're gonna accomplish the objectives and goals for this thinking with an end in mind and then each day kind of teaching, working with these students and we may need to hit another idea from another angle so they better understand it and so we may need to shift things around. You are always teaching a new group of students, you're always trying to find a new way to meet their learning needs, [the instruction] needs to make them excited and passionate about science and understand why it matters to them, so [I am] always planning, always got the unit plan each day to day kind of reassessing, alright, what are we gonna do here, shifting things around, adding in a new idea, taking out something that's maybe redundant and then within a block shifting things around, trying to meet that activity you got to be well-prepared and also flexible. (Mr. Hall, Interview #1)

Upon the selection of *Clinical Clark*, some of the teachers stressed the application of science to a real life. For example, Ms. Franklin wanted to bring in more real life examples that are complex. However, she expressed disappointment with some materials and even with her laboratory activities because there were not sufficient for students to experience a real life application and did not motivate students enough.

> You have a lesson that's isolated and then you really can't see a real life application-like we did an egg lab, but in reality, who really puts their eggs… in real life, who put their

> eggs in water and corn syrup? That's not really a "real life" application. So, I hope that they can see, okay, hypertonic solutions, hypotonic solutions, oh, this [the calf's illness] is a consequence of it [homeostatic balance] not being correct. (Ms. Franklin, Interview #1)

On the other hand, Mr. Palmer, Ms. Franklin, and Mr. Lennon, who represent all teachers except Mr. Hall who teach in the public schools, reported that they referred to the state standards and frameworks units to guide their decisions about which materials to use. In making decisions about using *Clinical Clark*, those three teachers looked at the information showing how this material relates to the NSTA standards and to the Georgia Performance Standards. Consider the following example(s).

Mr. Palmer's reason for selecting instructional materials centered on the *Georgia Performance Standards*, which were written specifically for the state of Georgia, as well as what he considered to be appropriate ways to get the students interested. Thus his evaluation of any material to be considered for use in the classroom had to meet his ideas of how it would interest students as well as how the materials fit into the standards. But foremost, he insisted that he would not use the material if it did not fit into the standards.

Likewise, Ms. Franklin had two requirements about which she was concerned when she planned a lesson. Whereas Mr. Palmer's dual concerns were student interest and the match of the materials to the standards, Ms. Franklin's concerns were identified as lesson structure and curriculum pace. Ms. Franklin's school principal required all teachers in the school to follow a protocol called EATS, where teachers have an Essential question, an Activating activity, an actual Teaching strategy, and then a Summarizing strategy. Furthermore, her department had a pacing guide that the whole biology department created collaboratively. She was concerned about keeping pace with the other biology teachers. In addition to those requirements she believed that her reflection on the past lesson that she had taught affected her selection of the other instructional materials. If she did not think the materials in her past teaching were sufficient, she would use the Internet to find something more interesting.

> When I realize it, I will look at the lesson and go, “Wow, this is really flat. I need to inject a little more life into it, uh, this just too boring, it’s not really teaching it as well as I can.” At that point, as I reexamine them in [terms of] what I’ve done before. Then I am saying, you know really I need to do better on this. So when I sit down and look at what I’ve done before that’s when I decide, okay, I need something else. (Ms. Franklin, Interview #1)

Summary

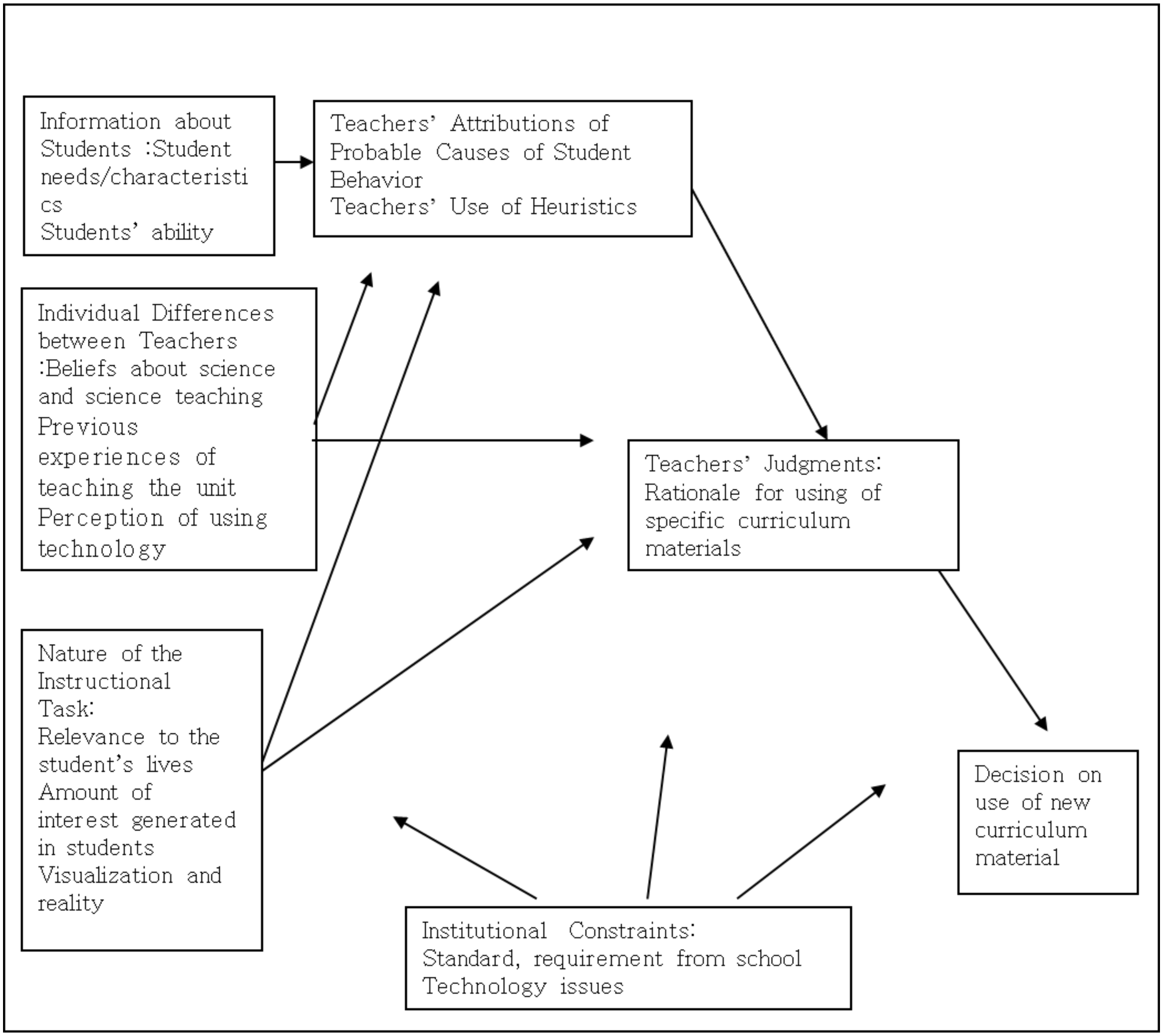
Shavelson & Stern (1981) identified some important factors contributing to teachers’ pedagogical judgments and decisions. (see Figure 1. Some factors contributing to teachers’ pedagogical judgments and decisions in chapter 2, p. 20) Their decision model posits that information is selected and integrated by teachers to reach a judgment or make a decision, in part, on the basis of a few heuristics and their attributions for the causes of events. In this study I examined what factors influence teachers’ decision-making about the use of the new inquiry-based curriculum materials prior to their in-class implementation of the materials. Based on the analysis of the teachers’ interviews, I specified the factors that the teachers considered to reach their decision on use of the new curriculum material, *Clinical Clark*.

Figure 4 illustrates factors that emerged from the analysis of the teachers’ talk regarding their planning decisions about using novel curricular materials based on 3-D models and animations. A comparison of their pre-interviews revealed that the teachers had previously had many common experiences and instructional sequence statements when teaching students the concept of osmosis. Furthermore, the teachers shared many of their views on the benefits of using technology-based curriculum materials. In the planning and actual teaching process, the teachers' views about how science should be taught guided their decisions on the selection of curriculum materials. The teachers considered a variety of information about students in planning the use of curriculum materials. Students' engagement also influenced the teacher's decisions about choosing new curriculum materials.

In selecting a new curricular material to use in class, the teachers took into account topic-specific considerations. They made decisions at a fine level within the overall subject. First of all, three teachers of the four public school teachers had to follow the state standards. Therefore, each examined how the new curriculum materials related to the standards. The fourth public school teacher, Mr. Hall, did not explicitly list the state standards as factors that he considers when selecting a new curriculum material. As science teachers, they evaluated how the material is visually presented; how much reality is reflected in the material; and how much it relates to daily life.

Figure 4

Factors Contributing to Teachers' Decisions on Using Novel Curricular Materials based on 3-D Computer Animations (modified from Shavelson & Stern(1981) in Chapter 2, p. xx)



Interactive: Implementing, Monitoring, & Regulating

This section describes the findings resulting from teachers' instructional implementation of the curriculum materials module titled *Clinical Clark.* The primary source of data was observations made in the teacher's classrooms. Based on the teachers' self-report of how they had taught osmosis in the past, the same basic instructional sequence was used even when *Clinical Clark* was introduced to the students. The findings related to the teachers' teaching are discussed in terms of the teachers' introductions of the materials, *Clinical Clark*, the teachers' interaction with the students, and the teachers' wrap up at the end of class. Further, the ways in which the teachers dealt with unexpected events such as technological issues and the different amounts of time required by the students to complete the *Clinical Clark* module are described. To create a context within which to discuss these events, I have provided details about what occurred during the observed lessons. Therefore, I have chosen to provide a description of each teacher's actions followed by possible explanations for their implementation decisions. Finally, I describe similarities and differences in each teacher's instruction using *Clinical Clark.*

In order to conduct an analysis of the degree to which teachers make use of modular curricular materials, I adopted a scale developed by Brown (2009). Brown focused on the level of shared responsibility between the teacher and the instructional materials and identified three levels of adaptation. These were labeled as offloading, adapting, and improvising. I will review these in the order presented above.

Brown & Edelson defined offloads as "shifts of curriculum design responsibility to the materials" (Brown & Edelson, 2003, p. 6) that are used to teach the subject matter content. This shift of responsibility in the way materials are used is common when teachers are unfamiliar with the content or pedagogy called for in the materials or when they are unfamiliar with the materials themselves. Additionally, teachers may offload responsibility onto materials that they perceive as well written and aligned with their own beliefs, curriculum standards, and the needs of their students.

In the middle of the scale is curriculum adaptation. Brown used this label to indicate situations in which upon the adoption of new materials to support teaching there was a more equal sharing of the responsibility of curriculum design between the teacher and the materials. Adaptation occurs when teachers use certain elements of the materials but also contribute their own design elements. This type of materials appropriation is used to account for contextual factors such as student needs and classroom constraints and also to better align instructional materials with learning goals (Brown, 2009; Brown & Edelson, 2003).

At the opposite end of the continuum is improvisation. In this form of instructional enactment of materials' usage, the teacher is the primary designer of the learning activity. That is, he or she may take an idea from a published resource, but the resulting instruction and class activities, while supporting similar goals to those of the resource, may represent a complete departure from the materials themselves. Given that improvisations represent complete departures from the curriculum materials, teachers' improvisation, which is often deliberate, may result in an opportunity for learning that is beyond the original plan for the materials, (Brown, 2009; Brown & Edelson, 2003) and can be either planned before instruction or occur during instruction, as part of the dynamic relationship between the planned and enacted curriculum.

Brown specifically stated that none of the three types of materials usage is necessarily negative. Any decision to use curricular materials in a specific way must be viewed in terms of the teacher's goals and the value of the particular resources. In this study, when the teachers were introduced to *Clinical Clark*, they highly valued the material's relevance to their students' lives, the amount of interest generated in students by the material, and the visualization and reality in the material as described in the earlier section (See figure 1). Based on their evaluation of the material, they planned to let students work with the module as a student-centered activity, which was the intent behind the way the material was designed. The teachers took the whole idea of *Clinical Clark* and significantly relied on the module, usually allowing the students to work through the materials entirely on their own.

In general, the teachers proceeded through the class sessions that involved the *Clinical Clark* module in three parts: introduction, working with the module, and wrapping-up. Because osmosis had already been taught to the students in a class session that occurred before the class used *Clinical Clark*, all of the teachers reviewed, at the beginning of the class, the concepts of diffusion and osmosis before introducing the students to *Clinical Clark*. The teachers explained to the students that each of them would play the role of a veterinarian trying to treat a sick calf. As will be shown in the coming sections, two teachers, Ms. Thorn and Mr. Hall, gave more detailed explanations about osmosis to their students than the other teachers did. After the introduction, the students worked through the *Clinical Clark* module. During the time when students were actually working with the *Clinical Clark* module, the teachers walked around the classroom and talked with the students individually. At the end of class, the teachers summarized Clark's case.

What happens in one teacher's classroom can be vastly different from that in another teacher's classroom, even if they decide to use the same materials in the same way (Park & Oliver, 2008). Therefore, each teacher's implementation of *Clinical Clark,* along with possible explanations for their implementation decisions, is discussed. This approach allowed me to more easily observe similarities and differences in each teacher's instruction using *Clinical Clark*.

In the planning process, the teachers did not make any changes in the activity because it was not open to change nor did they make detailed lesson plans. All of the teachers largely relied on the curriculum material and they primarily offloaded responsibility for teaching the science content onto the module, *Clinical Clark*. However, when I analyzed what I observed in each teacher's instruction, I found there was a continuum of offloading in their implementation of the module, from minimal to full. In the next few pages, I will explain how the scale of minimal to full matches up to the three levels of offloading that Brown identified.

I created a rubric for classifying the amount of offloading of students' learning that occured onto the module. During the first session of data analysis, I noted the teachers' actions that I observed during their implementation of *Clinical Clark* (See Table 7). Then, I broke down the teacher's reasons for the action into the three aspects. I labeled these three aspects as follows: content – referring to the reasons given by the teachers that were interpreted as taking subject matter content teaching responsibility, affect – referring to the reasons given by teachers that were interpreted as taking motivation of student affect, and action/technology issue – referring to the reasons given by teachers that were interpreted as taking responsibility to make the students' activity because even though the teachers enact similar instructional actions, the purpose for those actions might be different. Table 8 provides the explanation about teachers' actions that play a role in offloading of instructional responsibility by teachers including the reason for each action. Finally, I used the actions and the purpose of the actions to investigate the type and characteristics of each teacher's overall offloading while they were using the module.

Table 7

The Teachers' Actions while Using Clinical Clark

Teacher's actions
Reviewing previously taught content • Review the content and connect it to the module • Short review of the content but not related to the module • Mention some words related to the content but do not review the content
Checking for understanding while students conduct module • Interact with the students about the topic • Strong teacher questioning skills during the activity • Limited questioning • Focused on students' affective responses
Following up and summarizing after the activity (and maybe on the next day) • Summarize the activity • Review most of the components of content in the module
Stopping the whole class to clarify content • If a common difficulty among the students was observed, the teacher intervened in the class
Creating a student worksheet • Based on student's ability, create a student worksheet to know their understanding through the module
Encouraging peer discussion during the activity • Use cooperative learning strategies

Table 8

Teachers' Actions that Play a Pole in Offloading of Instructional Responsibility by Teachers

Teacher's Action	The purpose of the action		
	Content	Affect	Action/Technical issue
Review of previously taught content	To redefine terms To refamiliarize students with concepts	To make comfortable To motivate	To remind them of lab processes
Checking for understanding while students conduct module	To offer clarification and extend student understanding	To command the attention and interest of the students	To make the students proceed to the next step in the program
Follow up and summarizing after the activity (and maybe on the next day)	To recap and reinforce the process and content in the program	To check how the students felt by doing the activity	N/A
Stopping whole class to clarify content	To explain what most students have difficulty understanding	N/A	To settle technological problems
Create a student worksheet	To help the students connect their knowledge to the activity and to accommodate content	N/A	To assess their performance on the activity

Encourage peer discussion during the activity	To make students work in teams to challenge each other and to test and defend their own possible solutions	To reduce the students' anxiety to working the new activity by make them working in teams	Because of the limited environments (computers)

According to the nature of the teachers' overall relationship with the curriculum materials observed in the classroom, I have ranged their implementation along a continuum and classified the teachers' offloading to *Total offloading, Modest offloading, and Minimal offloading* in order to describe the degree to which the teachers offloaded the responsibility for teaching onto the material. There are three teacher actions (i.e., review of previously taught content, checking for understanding, and follow-up and summarizing) that are the essential criteria to define the continuum of offloading because these actions mainly affect accomplishing the biology content learning objectives developed by the team that created *Clinical Clark* (see Appendix A). If a teacher demonstrates the three actions and the actions were related to content and aimed at improving students' learning, it is defined as minimal offloading. If the teacher demonstrates one or two actions and its purpose was related to *content*, it was defined as modest offloading. For instance, if the teacher reviewed the concept of osmosis that the students had been taught previously and the purpose of the review was to familiarize students with the concept, the teacher is taking some responsibility for teaching from the material. The action that can be explained as teachers' responsibility is essential to defining the teachers' overall offloading. If the teacher demonstrates none of the actions or even if they did one or more of the actions but the reason is not related to the biology content learning objectives, it was defined as total offloading. Table 9 provides the characteristics of *Total offloading, Modest offloading, and*

Minimal offloading as well as the description of each teacher's implementation using *Clinical Clark.* The details of each teacher's implementation will follow.

Table 9

The Classification of the Teachers' Offloading

	Minimal Offloading	Modest Offloading	Total Offloading
Characteristics	The teacher checks students' understanding and helps students make connections while using the curriculum material. The teacher increases the amount of personal assistance to keep the student on task. The teacher takes actions that contribute to a lesson objective or goal	The teacher conducts a mini-lesson before or after using the curriculum material to improve the students' understandings.	The teacher serves to communicate and clarify the steps of the lesson. All actions are related to managing the students' behavior and time
Examples	-Prepare students to be ready for the program in terms of knowledge (a small review lecture) -High interactivity with	-Insert another activity before using Clark, e.g., used Osy game to review osmosis - Provide a review of	-Focused on checking that the program is working well on the students' computers. -Focused on handling

	the individual students during the activity. - Made improvisational decision to split up the class.	osmosis prior to having the students do the program - Debrief or give an analogy after the students finish the program.	technological issues. -Osy game was played to use up extra time.
Teachers	Mr. Hall(and Ms. Rhodes)	Ms. Thorn(and Ms. Mitchell), Mr. Watt	Mr. Palmer, Ms. Franklin, Mr. Lennon

Total Offloading Case 1: Mr. Palmer

Mr. Palmer divided the students into groups of two when they came into classroom. He had enough computers for everybody to work individually, but he thought groups of two working together on *Clinical Clark* might be better. In explaining the reason, he stated, “I just gave it a try in groups of two first. I thought in groups of two they might be able to do *Clinical Clark* a little bit easier and help each other out and come up with the right ideas and stuff. In the future, maybe everybody does their own (Mr. Palmer, Interview #2)”

His idea of working in groups parallels the reason he chose the honors biology class for the use of the materials. He thought honors students would be focused and would understand what is going on in the program because, in his view, most of them already had learned the concept of tonicity. He felt that with this prior knowledge they would understand what was going on in the program. Thus, he expected to be able to anticipate how students in the general classes would use the materials, and he would have a head start on how to handle any problems in the future.

He directed the students to go into the school's common folder and open the *Clinical Clark* program. The directions were also written in a paper form that the students received when they came into the classroom. However, it took quite a long time to get some students logged in at first because the multiple downloading from the school network made the launch of the program slow. When someone had trouble starting the program, he loaded the software directly on the laptops using a flash drive.

In the written directions that Mr. Palmer gave to his students, he also provided information about key functions within the module. For the reason that he prepared the written directions, he said that he had trouble remembering which keys do what while he played with the materials the other day, so he put all the directions on the printout so the students could look at it while they were working. However, he thought that it probably wouldn't be a problem for them because the students today are "computer savvy." The printout he gave the students is included in Appendix D.

Mr. Palmer's school uses a 4X4 block schedule and as a result had one-and-one-half-hour class periods. Mr. Palmer devoted the entire class period to *Clinical Clark*. As they worked with the program, the students didn't raise their hands to ask questions related to the procedure of the program. They seemed to clearly understand how to run the software or what to do next. While the students were working with *Clinical Clark*, Mr. Palmer walked around, observed, and asked questions like "How is it going?" or provided encouragement like, "Save him!" These comments were intended to encourage the students' interest of Clark's case and to check whether the program was working well.

During the class period that I observed all the students finished *Clinical Clark*. However, some took the whole period while others finished sooner, approximately 20 minutes earlier. Mr.

Palmer mentioned that the quicker students spent less time playing around with and getting used the interface of the program and launched the program more quickly as well. As individual students finished *Clinical Clark,* Mr. Palmer allowed them to play the *Osy Osmosis* game. Mr. Palmer didn't get a chance to debrief the students as a whole group after the class, at least not on the same day. On the following day he reported that he summarized *Clinical Clark* to the students.

During the implementation that was observed, Mr. Palmer's use of *Clinical Clark* can be classified under the curriculum implementation label of offloading. What was observed and confirmed by the data analysis was that he placed instructional responsibility for teaching about osmosis onto the materials. It is important to point out that his use of *Clinical Clark* came after he had already taught osmosis and diffusion. Since Mr. Palmer had already taught osmosis and diffusion, he may not have felt a need to review. Furthermore, his significant reliance on the program made him focus on making sure that the program was working smoothly.

Total Offloading Case 2: Ms. Franklin

Ms. Franklin implemented *Clinical Clark* with her class in the school's computer lab. The class duration was 55 minutes, which was the shortest class period time among the participant teachers' classes. When the students came into the computer lab, Ms. Franklin assigned a specific number of the computer station where the student would work. Then, she distributed a student worksheet in the beginning of the class. The worksheet included 5 questions related to *Clinical Clark* (See Appendix E). Some of the questions were about basic concepts of osmosis and diffusion, and some of the questions were pulled from the program because she thought the answers to the questions could tell her how well the students understood the concepts in the module. She told the students to fill out the paper. While she walked around, she read the answers that the students wrote on the paper and she started discussions with individual students, during which she checked their understanding of the basic concepts of osmosis. However, her discussions with students were limited just to the osmosis concept, not included the other Biology content learning objectives in *Clinical Clark* module such as understanding maintenance of homeostasis or applying the osmosis concept to the case of hyponatremia.

Compared to students in other schools, Ms. Franklin's students raised their hands to ask procedural questions more frequently. A lot of them were asking, "What do I do now?", "I don't know what to do now", and "I don't know how to answer this question. The students seemed to want to finish the program in 55 minutes, and this might have hindered them from taking enough time to explore the interface of the program or encouraged them just to try it in their own ways. Another thing I observed in Ms. Franklin's discussion with individual students was that she kept trying to bring the basic concept of osmosis to any questions that the *Clinical Clark* module asked the students. Her actions can be explained by her opinions about the students' abilities:

> My students this year are the lowest functioning group I've had in all the years I have taught. They came to me with very little science knowledge. They have no work ethic. They do very little in class, you know, there are exceptions, but as a whole, if I say, "Here is an assignment, work on it," you know, I have to walk around and make sure they're doing it otherwise they wouldn't do it, but they do, uhuh … I would say a majority of my students will do no homework and they do not study—a majority. There are exceptions. They don't have good grades. It's not just me. I am talking with other tenth grade teachers as well. In other subjects and they're seeing the same things. You know, it's just for some reason, um, this is how they are and in other years I'll have

outstanding students, but it's kind of like, you know, playing a game like poker, sometimes and sometimes you don't get a good hand and this is kind of just the luck of the draw. (Ms. Franklin, Interview #2)

Like Mr. Palmer, Ms. Franklin offloaded the students' learning onto the *Clinical Clark* module. Her discussions with the students during the implementation of *Clinical Clark* focused on the basic concepts unrelated to extending student understanding even though her earlier discussion with me had focused on real life "application." She had low confidence in her students' science abilities as well as their performance and expected that half of the students would not understand the science content within the *Clinical Clark* module. Ms. Franklin's implementation was not only influenced by her perception of her students' ability, but also by her responsibility for the upcoming midterm examination. At the time this research was conducted, the students' midterm examination was a week away, and she wanted the class to have the chance to review osmosis before the midterm. Ultimately, she believed that half of her students understood the ideas in the material but needed additional review of the ideas in the module later.

Total Offloading Case 3: Mr. Lennon

Mr. Lennon's class, which was observed for this research study, was conducted in a business education classroom that had the necessary computers for *Clinical Clark*. The science class was zoology, and the students were 11th and 12th graders with a majority of them being seniors. All of the students had previously taken an introductory biology course. Before the day of the class, Mr. Lennon had showed the students *Clinical Clark* as well as related basic information using a projector in his classroom. He wanted to prepare them for the session in which they would be using the materials. This enhanced introduction of the material, he believed, would help the students feel eager to get started when they went in the classroom. While the students came into the business classroom and sat down, Mr. Lennon wrote the directions, on the board at the front of the room, that the students should follow to start the program. Since, he had talked to them about *Clinical Clark* the previous day, he let them just get started without giving any additional introduction.

Mr. Lennon wanted the students to understand that working with animals as a veterinarian takes more than just liking animals. He spoke to the whole class while walking around the classroom.

> This is a lot of work, but if you're gonna be a vet it's not that you just go and pat the dog on the butt some other way. You actually have to have the problem solving skills, you know, to figure out what's going on. (Mr. Lennon, Observation)

Also, while walking he encouraged the students to solve Clark's problem like scientists and to write their thoughts precisely and specifically. For the students' content knowledge, Mr. Lennon assumed that the students understood the basic principles of osmosis and diffusion before they came to zoology because they are in the upper grades and have taken an introductory biology course. Also, since he had reviewed osmosis the previous day, he also had some reason to know what they understood about osmosis and diffusion. Therefore, he thought what they should do was to take those basics and then actually to do the science. He offloaded all the responsibility of students' learning in class on the *Clinical Clark* module. During the time that the students were actively engaged with the module, Mr. Lennon did not engage in in-depth discussion with individual students about the processes that were being taught within the module. Rather he spent his "instructional" time speaking to the entire class. His goal with this form of teaching was not specifically aimed at the content of osmosis but rather was to motivate them to write their answers to the embedded questions within the module like scientists.

Modest Offloading Case 1: Ms. Thorn and Ms. Mitchell

Ms. Thorn's approach to the teaching of osmosis using the *Clinical Clark* module differed significantly from that of the other teachers as she had used an additional software game related to osmosis before using the *Clinical Clark*. Ms. Thorn had spent 30 minutes of the previous day's class letting the students play the *Osy* game. The course content unit that included osmosis had been taught a month previously. Ms. Thorn reported that she did not know how much the students had remembered about osmosis from that prior unit, thus she wanted them to play the *Osy* game first to refresh their memories. The first day she let them play for 15 minutes to 20 minutes and then she said, "Stop, everybody stop." At this point she asked the students to lower their screens a little bit so they could see her. Then she asked them a pair of questions (paraphrased here): "What was this activity that we were doing?" "What was this an example of?" Then she reviewed the content about osmosis that she had taught them in the previous month. During her review, Ms. Thorn continued to ask the students about the osmosis-related content. One of the students remembered osmosis and another remembered terminology associated with osmosis (e.g., tonicity, hypertonic, hypotonic, and isotonic). During the remainder of that class meeting, she asked them to proceed with loading the *Clinical Clark* software but told them not to use it yet. Her motivation in structuring the class session in this was to avoid spending time to load the program the following day when they came in.

The next day Ms. Thorn told her students about the plan for that day's instructional activity. Although case study was a teaching method that she frequently utilized, this was the first time she had used it with these students. She introduced the *Clinical Clark* module and specifically the medical problem of the calf. She told the students that they were going to play the role of veterinarians. In this role, one of their primary responsibilities, like that of a real veterinarian, was to cure a sick animal. She showed them how the software program would work by projecting it on a screen. While giving this module specific instruction, she specifically pointed the students to the use of the medical reference and what key stokes were used to complete certain other aspects of the program. Then she had them proceed on their own. Her teaching about the specifics of the module was not conducted in a directive way like saying, “Point and click here.” Instead, she showed some tips on the projector related to the difficulties she had experienced when she had used the materials by herself.

Ms. Thorn wanted to see the students conducting investigations immediately. She observed them as they spent about 10 minutes floundering, confused, or upset because *Clark* was having seizures. Once they had achieved that level of accomplishment, it did not take them long to proceed to the collection and analysis of data. The students began to “start putting it together.” Ms. Thorn walked around and had them tell her what they were doing and why. Most of the questions she asked to the students while they were doing the activity were “why” questions. In her interview about her students, she commented that her students (in introductory biology) required a great deal of shepherding compared to honors students. Furthermore, in her pre-interview, she doubted her students would understand the logic of this case study as much as the honors class. However, she tried to move them beyond learning of basic concepts by asking “why” questions. She wanted the students to recognize the relevance of the biology content-osmosis they were learning.

> To me, what was the most important thing is that it puts them in the role of veterinarian or a farmer who is raising cattle … who's got an issue that needs to be dealt with … by collecting data and formulating a response based on evidence. So them seeing that contextual, you know, real life reason answers for me the "So what?" question. (Ms. Thorn, Interview #2)

As was mentioned earlier when describing her rationale for selecting curriculum materials, Ms. Thorn believed it was important to teach in a variety of ways because the students in the class will approach learning in a variety of ways. She felt the *Clinical Clark* case study raised their level of enthusiasm for a lesson by showing the inside of the brain and the biological processes. Also, in response to my question of what the most important point in *Clinical Clark* was, she replied that it answered the "So what?" question. For these reasons, she offloaded the materials like other teachers; in other words, she used them without changing or adding to them. However, during the implementation, she tried to get the most out of the material by guiding her students to do more than just engage in visualization. Ms. Thorn's instructional use of "why" questions, that probed student recognition of the relevance of the biology content they were learning, was a means to connect to an earlier discussion of the material in a previous unit as well as her desire for students to become independent thinkers.

Ms. Thorn had three introductory biology classes. While the first class was taught by Ms. Thorn, her student teacher, Ms. Mitchell, observed from the back of the classroom and took notes. Based on her observation of Ms. Thorn's class, Ms. Mitchell taught the two subsequent sections. The way Ms. Mitchell conducted the class in the use of *Clinical Clark* was basically the same as Ms. Thorn's instruction, but her classes were different from Ms. Thorn's class in two respects. First, she spent about twice as much time introducing the software to her class and gave much more detailed instructions, explaining everything the students would do, step by step. The reason for this change was explained by her perceptions of the students' ability and her experience with the materials. She thought that 9th grader students had not really retained much of the biology content related to osmosis from the lecture. Even though the students had already learned osmosis a couple of months previously, without practice solving these types of exercises, they could not easily apply the concept to a real life example like Clark. For this reason, she explained more details of osmosis in the beginning of the class. Furthermore, Ms. Mitchell thought that the students had a less well developed conception of the content related to osmosis after the instruction than Ms. Thorn believed, so she decided that getting the students to express what they knew as well as to reaffirm what they knew could add to their knowledge.

Based on her observation of Ms. Thorn's class, Ms. Mitchell thought she needed to give a more directive explanation of how to use the program.

> I think that… like it takes them awhile to familiarize themselves with that interface for one and also to figure out what they have to do, what they have to press at that point even if they've gone through the tutorial so it still takes them a second to adjust to how they're going to go about working through it, but I think, I haven't seen very many students do it, but the first group rushed through the tutorial and then they didn't really know how to continue when they started playing the game.(Ms. Mitchell, Interview #2)

Ms. Mitchell made the decision to show the entire sequence of slides within the tutorial through a projector and let their students follow with her step by step. It took more time than when the students just opened up the program and started the module. But in her view, this approach was the most appropriate way to ensure that the students had proceeded through the tutorial thoroughly.

While the students were working on *Clinical Clark*, Ms. Mitchell watched them fill in their answers to the questions within the module. She was particularly interested in student thinking and actions in the situation that arose when they had to determine which treatment would be best. Ms. Mitchell thought that the arrangement of questions in the module was good. In particular, she felt that having an open-ended question in sequence after the multiple choice question was really good. This sequence of assessments allowed students to figure out how to answer the question of why they had chosen a particular treatment. If the students were able to answer that question correctly and if they could tell why isotonic or hypotonic would work less well, then that, she believed, gave her good information of whether they understood the difference between those concentrations of salt solution. She asked the students questions such as: what does hyper mean? What does hypo mean? Where is the water moving? And also she emphasized the point that they were injecting the treatment into the blood as opposed to injecting it somewhere else. All of these actions were part of Ms. Mitchell's intentional instructional effort to make it easier for the students to answer the question as to why the hypertonic solution—which was the solution that most of them had chosen—works well.

Overall, Ms. Mitchell went through the same steps that Ms. Thorn had when she taught the class with *Clinical Clark*. For example, in the introduction, she drew the same picture that Ms. Thorn had in order to explain osmosis as well as to define the terms, hypertonic, isotonic, and hypotonic. In similar manner, she essentially repeated the instructions that Ms. Thorn gave the students in an earlier class section. Just as Ms. Thorn had done, she also offloaded the subject matter content of the module. However, Ms. Mitchell made an effort to teach the science content of osmosis before the students used *Clinical Clark* by reviewing osmosis. The fact that she followed Ms. Thorn's implementation style might be explained by Ms. Mitchell's inexperience of teaching osmosis because she is a student teacher who does not have the freedom to choose. Nonetheless, Ms. Mitchell did reflect on her own perceptions about the students and what she felt during the observation of Ms. Thorn's class in her teaching. As a result, she spent more time to reaffirm the students' knowledge about osmosis before they began the module. However, in terms of checking students' understanding while the students were doing the activity, Ms. Mitchell' s discussion with the students did not differ from that of Ms. Thorn.

What was observed and confirmed by the data analysis was that Ms. Thorn and Ms. Mitchell placed instructional responsibility for teaching about osmosis onto the materials. However, they also took some responsibility for teaching over the material by doing instructional actions during the classes— a mini-lesson before using the curriculum material and discussion with students while the students were doing the activity—to improve the students' learning.

Modest Offloading Case 2: Mr. Watt

As described earlier, Mr. Watt' teaching style was to cover a smaller number of topics in great depth. He expressed his intentions in the following manner: "That's [in-depth learning] important instead of trying to be a stone skipping across the water covering lots of topics with no depth." His teaching context allowed him to put his beliefs into practice; the school was a private school that allowed him to create his own curriculum. The class in which he implemented *Clinical Clark* was for introductory biology honors students who, according to Mr. Watt, were highly capable of dealing with biology at the college level. Mr. Watt had taught diffusion, osmosis, and facilitated diffusion in the days before using the *Clinical Clark* module. On the previous day he had asked the students to download the software onto their laptops from the school server, and they already had the program installed on their laptop computers when they came into class. At the beginning of the class period, he allowed the students to start the software program immediately.

When starting the program, many of the students were having trouble booting-up *Clinical Clark*; on most of their computers the boot-up process took a very long time. Mr. Watt responded to this situation by having all the students shut down the computers and restart them. Afterwards, he instructed them to restart *Clinical Clark*. This process apparently served to clear the RAM memory of the computers so most of the computers would run *Clinical Clark*. Even after this procedure, there were still some students who could not open the program. For them, Mr. Watt went around with some thumb drives on which he had pre-loaded the program and replaced the program they had downloaded from the server with those on the thumb drives. He guessed that the downloaded version of the program from the network had been corrupted in some unknown way. A second possible problem was the age of the laptop computers. They were in their third year having been originally issued to most of those students (now in the 9th grade) at the start of their 7th grade year.

After he solved the technical problems he was able to speak with each of the students individually. His questions to students did not focus only on osmosis but went beyond osmosis to the entire biological organism (the calf, Clark). The discussion with the students focused on the biological processes related to the calf's seizures. He used questions, which he posed to the individual students, to stimulate this discussion. Examples of the questions he used while the students were using the program included: Why does pressure cause the convulsions? Why does pressure cause the seizures in Clark? What is it about the pressure on the brain cells that actually causes them to fail? He led the students to look for a deeper understanding of what actually was happening at the cellular level to cause Clark's seizure.

At the end of the class, the biology content that he debriefed with the students, now as a whole class, was also related to making the connections about pressure. For instance, he asked then to consider why pressure builds up in the brain. He did not choose to review the basic concepts like what osmosis is and what hypertonic, isotonic, and hypotonic mean. Instead, he built on relevant examples that the students already knew such as the buildup of water pressure within plant cells due to the structure of the cell wall. Mr. Watt compared the hard skull outside the brain to the plant cell wall. This pressure occurs for the same reasons, i.e., hypertonic solution inside the cell, and Mr. Watt believed his students were capable of transference to the module’s biological context.

Mr. Watts demonstrated two actions, namely reviewing after using the module and checking the students’ understanding and the purpose of the actions was related to content and aimed to extend and reinforce students’ understanding. Mr. Watts’s use of *Clinical Clark,* like Ms. Thorn and Ms. Mitchell, can be classified to modest offloading.

Minimal Offloading Case 1: Mr. Hall & Ms. Rhodes

Finally, Mr. Hall’s introductory biology class was taught by a student teacher, Ms. Rhodes. They jointly planned the lessons Ms. Rhodes was going to teach and Mr. Hall provided all of the instructional materials that he had used previously to teach concepts related to osmosis. In this way, Mr. Hall followed the same pattern as Ms. Thorn had done for her student teacher, Ms. Mitchell. The contrast between the two pairs came in the instructional enactment. In contrast to Mr. Hall and Ms. Rhodes, Ms. Thorn silently observed while Ms. Mitchell taught the class. Mr. Hall intervened in the class as Ms. Rhodes taught, whenever he thought it was necessary. One week ahead of the class in which they had planned to use *Clinical Clark*, Ms. Rhodes had already taught the students osmosis. In particular, in her class lecture, she had explained vocabulary words like hypertonic, isotonic, and hypotonic, homeostasis, equilibrium, and osmosis.

When the students came into the classroom, Ms. Rhodes distributed an 8" x 4" piece of paper on which were written two osmosis review questions. Ms. Rhodes believed that, due to this prior instruction, the students already knew the science content of osmosis and the tonicity-related terminology. She reminded them of the prior instruction with these questions. After that, Ms. Rhodes introduced *Clinical Clark* as an opportunity to solve a medical mystery, almost like a veterinary version of the TV show, *House*, and Mr. Hall said they were going to work in teams, groups of two or three. He and Ms. Rhodes had divided the students into mixed-ability groups before the activity. Mr. Hall and Ms. Rhodes expected that the students in a group would help each other by working the programs together. He explained to the students that scientists collaborate, pull their ideas together, discuss with each other, and justify their decisions. He discussed with them that he wanted contributions from all group members and that assessment would be based on each group's answers. Then they moved to the school's media center where the computers were located. The directions about how to start the program were written on the board in the media center. The students started the program and the two teachers began helping them to work on a program. At first, Mr. Hall discussed with the students the brain structure and neurons and how neurons fire. In the post-interview, Mr. Hall stated he thought his students lacked prior knowledge of brain structure and neurons so he felt that he needed to discuss that biology content with the students first in order to fill in their lack of the prior knowledge. Mr. Hall and Ms. Rhodes both tried to refine the students' understanding to allow them to apply osmosis to solve Clark's medical problem. They kept asking the students about the relationship between osmosis and the symptoms being exhibited by the calf to encourage the students to transfer what the students had learned about osmosis to a real life problem. Their questions were generally guiding questions- step by step questions trying to steer the students to the right answer like “What is this?”, “What is sodium concentration there?”, “So, where is the water moving?” and etc.

In Mr. Hall’s school, the *Clinical Clark* module would only run only in ten computers because the stations in the computer lab were networked in clusters of 3-5 computers to one shared CPU. However, Mr. Hall prepared for this technology limitation by allowing the students to work in groups before the class. He stated his feelings about the issue as follows: “I think in some ways the technical issue is presenting a new opportunity for students to act as scientists and collaborate in teams and then solve that medical mystery like a team of diagnosticians.” (Interview #1) He monitored the situation to make sure the students were working together to come up with their group’s final answer that they were typing up.

The time the groups took to finish the program varied. The group dynamics and the types of personalities seemed to affect the time the students took. Groups that finished the program early were allowed to play the *Osy* game, and when the half of the groups had finished, Ms. Rhodes moved to the classroom with them and summarized Clark’s case. She explained various aspects, like what was happening, why the water was moving out, and what was going in the brain. Some groups were still working as she discussed Clark’s case with other groups. Those groups whose members had not finished kept working, and Mr. Hall helped them continue to pursue the module until they finished. Although the variation of the completion time between groups was not expected, the collaboration between Ms. Rhodes and Mr. Hall led to the improvisational decision of splitting up the class so that Ms. Rhodes took the students who had finished back to the classroom and Mr. Hall stayed behind in the lab with the ones who were still working on the program.

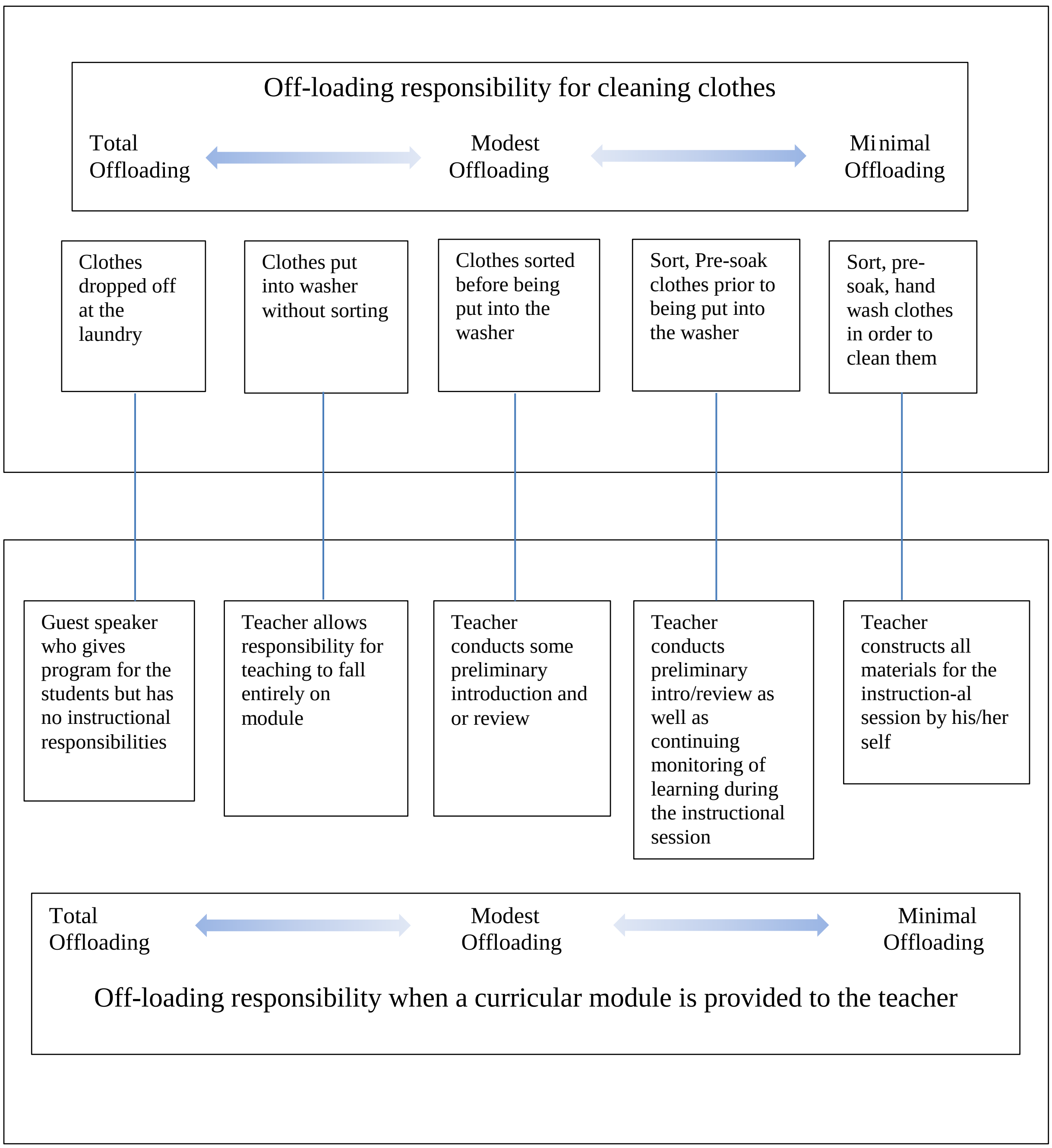
Like other teachers, when they were planning the lesson before instruction, Mr. Hall and Ms. Rhodes seemed to offload the responsibility for students' learning onto *Clinical Clark*. They did not make any changes to the module, *Clinical Clark*. However, their implementation during instruction differed from that of the other teachers. They reviewed osmosis before/after doing the module, and the purpose of the review was to remind the students of the content. Their interactivity with students was very high; they went to each student to assess the degree to which they understood the science content in the module, they checked students' understanding and helped students make connections while using the curriculum material. Besides these content related actions, they encouraged peer discussion during the activity so that students could challenge each other and defend their own possible explanations.

Summary

To understand what offloading means, a senior science education professor used the metaphor of cleaning clothes to illustrate the continuum of teachers' instructional offloading when using the curriculum materials (figure 5). In this study, I premised that there must be a difference between when students use the module by themselves online outside of school and when they use the module with a teacher in the classroom. If the teacher or curriculum developer has the students use the module as a homework assignment without any instructional interference, the case could be described as total offloading as the teacher offloads the responsibility for students' learning onto the module. In the metaphor of cleaning clothes, total offloading is like teachers having students simply drop the cloths off at a laundry. However, to really clean the clothes, there are cleaning options that make the process more effective, like sorting, pre-soaking, extra rinse, etc. Likewise, at the other end of the offloading continuum, the teacher could carry out various actions to help students understand such as some offering a preliminary introduction and/or review, and monitoring the students' learning.

Figure 5

Instructional Contrasts to the Cleaning Clothes Metaphor



In this section, the teachers' actions while implementing *Clinical Clark* were described and explanations for their implementation decisions were discussed. All of the teachers felt confident that using the curriculum material would be beneficial to their students in terms of enacting scientific inquiry. Based on their rationales for using the module presented in the earlier section, the teachers offloaded responsibility for teaching the science content onto the module known here as *Clinical Clark*. They did this because they perceived the module to be well written and aligned with their own beliefs, curriculum standards, and the needs of their students.

Each of the teachers developed a high level of familiarity with the *Clinical Clark* module prior to using it in their biology classes. As a result the teachers recognized that the module was a strong tool to teach the concept of osmosis and its related ideas to their students. This comfort level with the material allowed the teachers to offload the science content responsibility onto the module. This decision was clearly one made in advance because each teacher chose to make an outline of the lesson rather than a detailed lesson plan as they normally had done. In the absence of a detailed lesson plan, the teachers were not preparing for the discussion that would have characterized their teaching of other biology topics in which these kinds of materials were not available. However, even though the teachers used the material in similar ways, they all had to make on-the-spot decisions about how to adapt them in response to specific classroom events (Remillard, 2005). The participant teachers emphasized different parts of *Clinical Clark* and led the students in slightly different ways. Table 8 is a comparison of the teachers' comparable actions observed during implementation and possible reasons for their actions.

Every class I observed had an instructional sequence that consisted of the teachers' introductions of the materials, the teachers' interaction with the students, and the teachers' wrap up at the end of class. In the introduction, the teachers described Clark's problem and the students' role as veterinarians. Each teacher reported that they used this strategy in order to increase students' interest in the activity. The teachers briefly reviewed the osmosis and tonicity-related terminology the students already had been taught before doing the activity. Some teachers drew pictures on the board to refresh students' memories about osmosis and others reviewed just by talking. The time the teachers spent to remind their students of the content knowledge varied according to their perception of the students' need.

The teachers spent the greater part of the class letting their students invest in the activity. While the students were working the module, the teachers put responsibility for student learning on the material, and this offloading of the curriculum material allowed them the time to interact with the students individually. All the teachers interacted with their students by questioning or discussing while the students were doing the activity. However, the degree of interaction with students was different. The fact that they offloaded the curriculum material did not mean the same implementation or the same class quality. Some teachers went to each student to assess the degree to which they understood the science content of module and to actively discuss the module so as to improve the students' understanding. Some teachers paid little attention to checking the students' learning as they proceeded through module. In other words, their discussion during the activity was not specific and not focused on individual students' understanding; they just checked whether the program worked well or spoke to the whole class. Depending on the teachers' interaction with students, even though they offloaded most of responsibility for students' leaning onto the curriculum material, some of the teachers were active agents who, through their work with their students, complemented the curriculum materials rather than merely being transmitters or implementers.

These teachers' different instructional styles observed during implementation of the module were mainly affected by contextual factors like the technology-related situation or teacher factors like their perspective of science teaching and the capabilities of their specific students. For instance, the teachers, Mr. Palmer and Mr. Watt who had problems loading the program on the computers, reported that they spent more time than they expected helping students start the program and less time than they expected discussing Clark's biological process with students during the activity. Mr. Palmer, in particular, spent most of the time checking that the program was working well rather than trying to discuss Clark's problem with individual students. One other context factor is the culture of accountability in schools and its impact that seems to lead teachers to focus on preparing students for tests. This focus especially seemed a concern of Ms. Franklin's. Her implementation decisions, in addition to being based on instructional time and student behavior, often reflected a concern with the concept of osmosis that would be assessed on the upcoming midterm.

The most important factor that influenced the teachers' implementation of *Clinical Clark* was their perception of their role in the activity. Three of the teachers focused on having a new activity for their students about osmosis through *Clinical Clark* itself and not the individual needs of their students in their planning and teaching. Their primary instructional strategy was that of provider and supervisor: They believed it was their responsibility to provide students with activities that were challenging and required students to create their own hypotheses. Further, these teachers wanted to prepare students to be able to pursue these goals while also directing them towards certain science ideas. Except when the students asked a question the teachers let the students investigate their own ideas and work on the activity on their own. On the other hand, the other teachers seemed to regard the activity as a chance to devote more time to giving individual students step-by-step explanations of the teaching materials.

Post-active: Assessing, Reflecting and Planning

This section describes three aspects of the teachers' experiences after using the *Clinical Clark* module. The first section deals with the teachers' assessment of students' engagement using *Clinical Clark*. The second section deals with their reflection on students' learning using *Clinical Clark*, while the third section examines their planning for future classes they might teach using *Clinical Clark* based on their post instructional interviews. In the post interviews, the teachers were asked to reflect on their lessons and respond to the following questions: (a) Did the instructional session go as expected? (b) What did they think of students' learning using the materials? (c) How would they use the materials if they were to teach with the material in future?

Given this emphasis on reflection in the third segment of the findings, it is important to establish the meaning of this term. The notion of reflection is not new and many researchers have referred to Dewey's ideas as key concepts in reflection (e.g., Stanley, 1998; Ward & McCotter, 2004). Dewey (1933) described reflection as a specialized form of thinking that moves beyond impulsive actions, actions based on trial and error, routine actions, or those that are guided by convention or endorsed by authority – all of which prevent individuals from engaging in much thought about the reasons for and effects of their actions. For a reflective approach to teaching in this study, I draw on the definition posited by Hatton and Smith (1995): reflection happens when teachers 'think about their practice in order to improve (p.33).'

There are multiple frameworks for looking at levels of reflection and range from just describing what happened in a lesson to the highest level of reflection that incorporates the fundamental pedagogical, ethical, moral, cultural, or political concerns. Hatton and Smith (1995) identified and described four levels of reflective writing labeled descriptive writing, descriptive reflection, dialogic reflection and critical reflection. For this study, Hatton and Smith's framework have been used to examine teachers' levels of reflection based on their post instructional interviews. The meaning of the levels is summarized below:

Description or Recall ('descriptive writing' in Hatton and Smith's framework): descriptions, statements of fact, beliefs, opinions, and feelings

Descriptive Reflection: descriptions of events with some attempt to provide reason/justification for the events or actions but in a descriptive way.

Dialogic Reflection: thinking about events, actions, situations with explanations from analytical or/and integrative of factors and perspectives

Critical Reflection: give reasons for events, decisions, or actions with fundamental pedagogical, ethical, moral cultural, or historical concerns

This framework was chosen as the analytical tool for this study as it is well established and it is representative of what the teachers focused on in their reflection of the class using *Clinical Clark* as well as the level of the teachers' reflections on the class. Table 10 presents the highest level of reflection for each teacher from the analysis of the interview data. The reflective categories that emerged from the qualitative analysis in the current study with examples from the data are shown in Appendix F. Reflective level with examples from data.

Table 10

Teachers' Levels of Reflection

Category	Level of Reflection: Description or Recall	Descriptive Reflection	Dialogic Reflection	Critical Reflection
Students' Engagement	Mr. Palmer, Mr. Lennon, Ms. Mitchell	Mr. Hall, Ms. Thorn, Ms. Franklin, Mr. Watts	-	-
Students' learning	Mr. Palmer, Ms. Franklin	Ms. Thorn, Mr. Lennon, Ms. Mitchell	Mr. Hall, Mr. Watts	-
Planning for future classes	Mr. Palmer, Ms. Franklin, Mr. Hall	Mr. Lennon	Ms. Mitchell, Mr. Watts	-

Students' engagement

The teachers' focus for their overall reflection regarding students' engagement was on the category of description or descriptive reflection. When they made comments on how the class had gone, their remarks were mostly focused on the evaluations of the *Clinical Clark* module, such as how the module played a role with regard to students' engagement in the activity, but they did not discuss or consider the view of others. They talked about why they had chosen the module and expressed a belief that it had worked well. For their reflection, all of the teachers who used the *Clinical Clark* software in this study felt that it was a powerful tool to gain student interest and encourage their active participation. However, they did not connect this reflection to the process of teaching and learning.

As is evident in Table 10, three of the teachers reflected at the description and recall level and four reflected at descriptive level and one teacher could write at dialogic level. None of the teachers' entries could be categorized at the dialogic or critical level. Mr. Palmer, Mr. Lennon, and Ms. Mitchell described how the students were engaged in doing the activity without making any attempt to provide justification. For instance, Mr. Palmer said that I felt like they[students] were very focused and intense." On the other hand, Mr. Hall, Ms. Thorn, Mr. Watts tried to provide the reason for their engagement in doing the activity. In talking about how the overall class went, Mr. Hall stated, "They seemed to be more empathetic with that situation. I felt like it had them more focused on their performance." Ms. Thorn involved not only a description of the students' engagement but some attempt to provide reason/justification for that.

> I think the fact that it's on the computer is fabulous and I think the kids really got into it, they were excited, the role of the visualization in getting the students to see the importance of a disorder in the body. (Ms. Thorn, Interview #3)

From the perspective of the teachers who made some attempt to provide explanation beyond mere recall, there were two main characteristics of the curriculum module that stimulated student engagement: The high quality of the images and animations, and the students' role in the activity. In discussing the class, Ms. Franklin stated, "if it looks like it's not of high quality, it's going to be boring to them and I could not get their attention, so [with] the high quality animation so they were, 'Oh yeah'." Ms. Thorn also thought the features of the computer software attracted the students to the activity. She said, "I think the fact that it's on the computer is fabulous and I think the kids really got into it, they were excited." In addition to describing their students' excitement about the module, she pointed out the role of the visualization in getting the students to see the importance of a disorder in the body. She thought while the students were fully engaged, as opposed to just listening to her, they responded seriously to the example of what is happening to the brain when the electrolyte balance was off.

In describing the other reason for their students' high engagement, Mr. Hall, Ms. Thorn, and Mr. Watts stated that working as veterinarians to help cure Clark allowed the students to enter the program and get more involved. The teachers thought the active role of the students in doing the activity made them just jump right in, do it without any reluctance, and be eager to give it a try. The teachers expressed they were very pleased that their students were eager to work on the activity.

Three teachers, Ms. Franklin, Mr. Watts, and Ms. Thorn expressed that they were surprised by their students' fast adaption to the interface of the program. They already knew contemporary students felt at home with technology before the class and had expected the students were going to familiarize themselves quickly with using the software, but they were amazed by how quickly the students were able to navigate the program. Ms. Franklin said, "They [students] did a good job, better than I did. They are always better at technology than I am." Mr. Watts continued to be impressed by how comfortable the students were with the technology because he started teaching long before this technology existed.

Students' learning

While the teachers evaluated how successfully the students had learned from the lesson, the comments of four teachers were mere recall or descriptive reflection like when they discussed about the students' engagement. Dialogic reflection was identified in two of the teachers. The evaluations conducted by the teachers had two major components; one of which was summative in nature while the other was more about how the students progressed. In the end, the teachers had great interest in and based much of their final evaluation of *Clinical Clark* on whether the students could understand the content in the module and whether they could complete the questions in the module. However, as the students progressed through the module, the teachers focused on three characteristics that they observed including: how they saw the students performing the program, the questions that the students raised in doing the program, and the discussions they had with the students during the activity.

All teachers constructed their thoughts about student learning from the Interactive phase-during teaching, particularly from the discussions with their students. Two teachers who were highly engaged with their students during the instructional sessions had more specific thoughts about the students' learning. Both Mr. Palmer and Ms. Franklin were categorized into the level of description or recall by stating just their feeling and guess without evidence of deeper consideration. Mr. Palmer was confident that the students got more some scientific terminology from using Clark, and also reinforced their idea of tonicity. However, most of the statements expressed by Mr. Palmer were comprised of feelings or beliefs. For instance, he expressed his hopes concerning wider outcomes. He stated, "Hopefully, it helped with that—maybe just to grasp a little bit better how everything functions together inside the body." On the other hand, Ms. Franklin thought her students learned about the consequences of osmosis causing an increased pressure due to a physiological imbalance. She expected half of her students could connect the science they learned to a medical disorder and its underlying biological processes. Ms. Franklin felt that she had lower expectations for this particular class than normal, but she also felt that this was possibly a reflection of this particular group of students.

On the other hand, students' learning related comments from Mr. Lennon, Ms. Mitchell and Ms. Thorn were classified to descriptive reflection. Mr. Lennon thought that students learned about the balance that the body or cells have to constantly maintain, homeostasis. The fact that the students saw what happened when they did the treatment, he believed, helped the students understand the importance of homeostasis. He also saw a benefit to the students when the treatment was wrong, they saw water was just leaving the blood vessels, which was making Clark worse. He expected 80 % of the students fully understood what was happening to Clark based on the discussion that he conducted with the students during the post-lesson debrief.

Ms. Thorn reported that she thought that this activity made the students see science within the context of real life. The program puts the idea of osmosis within an organism into context, which helped them to remember the concept of osmosis or tonicity. However, she was unsure of how much they understood the whole picture of Clark's story across the complete time period from first beginning to show signs of seizure until curing the seizure. She stated, "I think the freshmen would have been just as engaged, and I think the freshmen would have figured out how to save Clark to win (Ms. Thorn, Interview #3)." However, she thought the students had difficulty wrapping up the whole process in *Clinical Clark*. The ability of the 9th graders to think about an event within a whole picture, she believed, might be insufficient. She expected that the upper class group would be able to see the whole picture better than the 9th graders.

On the other hand, Ms. Mitchell (Ms. Thorn's student teacher) judged that the students were able to really understand why the water moves, and to really notice that the water was moving out of the blood. However, she was concerned that their ability to retain the concept might not last for a long time. She believed that, to a great extent, their learning was determined by how well they had reviewed osmosis before they went into the program. That explained why her implementation had a longer introduction compared to Ms. Thorn.

Lastly, Mr. Hall and Mr. Watts were classified to dialogic reflection in terms that they gained understanding of the students' learning from their intense interaction with students and tried to generate solutions to help the students learn.

> In talking with the students, I remember being very impressed by their level of understanding. They were able to answer my leading questions, "What would happen if you did this? Why did this happen? And so forth.
>
> [after reading students' responses] I learned, I need to be more specific about the insight and depth, they need to demonstrate their insight in a very concrete way in their answers. (Mr. Watts, Interview #3)

Mr. Watts thought that when the students went through the module, the main two areas of learning were: the reinforcement of basic principles of water movement and the realization that those principles applied to the entire organism. At the cellular level, he thought the students learned the processes they had talked about when drawing cells on the board, for example, putting different solutions on different sides of a membrane and then seeing how the water level changes. At the whole organism level, they understood that what happened at the cellular level would not affect just the membrane; rather, it could affect the entire organ by seeing the calf having seizures. He thought the material, at least, gave the students an opportunity to think about how the principles that were occurring at the cellular level were actually applicable to the entire organism. Mr. Hall said that all the students understood that tonicity is relative and changes in tonicity due to illness or other causes can upset the normal homeostatic balance of a biological system. However, he stated that he noticed a few of the students did not understand all of the questions embedded within the case study module. In particular, they struggled with answering some of the bigger questions asking for a treatment summary and case summary. After Ms. Rhodes explained the activity to them again the next day—he said she really explained it all the way through with them—he felt the students understood the whole activity. He believed that the extra recapping activity by the teacher, like whole group discussion after finishing the activity, was necessary for the students to conceptualize the activity in their minds.

Evaluating students' understanding requires deeper and more critical reflection based on evidence from observation of students' behavior or interaction with students. In the interactive stage, Mr. Hall and Mr. Watts were the teachers whose engagement with students was very high. They expressed their thoughts on what the students learned and what they did not understand from the lesson, but their reflection on students' understanding was more specific than others

Future use of the material

When asked about the future use of the material, all the teachers responded positively about the material again in future. All of the teachers used the word "definitely" when asked if they would use it again. Their next plans were not specific, but mostly they would use the material within the unit including osmosis. Three of the teachers included what they learned from the class using the curriculum material in their future planning, and the others did not. The level of the teachers' planning for future classes related to their utilization the students' responses (see Table 11).

Table 11

Teachers' Utilization the Students' Responses and Level of Reflection about Planning for Future Classes

Teachers	Utilization the students' responses	Level of Reflection about Planning for future classes
Mr. Palmer	-	Description
Ms. Franklin	Check on completion	Description
Mr. Lennon	Read	Descriptive Reflection
Mr. Watts	Read and Grade	Dialogic Reflection
Ms. Thorn(Ms. Mitchell)	Read and Grade	Dialogic Reflection
Mr. Hall	Check on completion	Description

Within the *Clinical Clark* module, each student's responses were saved as an HTML file with the name which the student entered when the program started running. As described in the section of teachers' implementation, the teachers used the questions as a means to check the students' understanding or as a springboard for discussion with students while they were doing the activity. The responses played the role of a benchmark for the teachers, allowing them to know how the students had done. In addition to the monitoring function during the activity, the responses could also have served as an assessment tool. In this study, four of the six teachers had planned to grade the students' responses after class. However, just two teachers, Ms. Mitchell and Mr. Watts, graded the responses and gave actual credit for the activity.

Three teachers did not utilize the responses after class as a mean of knowing students' understanding. For example, Mr. Palmer was not able to collect the students' responses because of a problem with his school's network. Mr. Hall had planned to grade the students' responses but he did not grade by the end of the semester. Ms. Franklin made an effort to see the students' learning by preparing a student worksheet containing a couple of concept questions and by distributing it, but there were no events that might be labeled as her reflection on it that had happened by the end of the study. She had the students place this worksheet into their notebooks, in which they kept all the papers they worked on in class. She stated that she was going to grade the worksheets as one part of the entire notebook grading. She usually graded their notebook, not so much for correct answers, but for effort and for the overall idea of "did they do it?"

Mr. Palmer could see a lot of possibilities for using it in the future. He was sure that it would help the students to be able to grasp osmosis and see what was going on. He, however, was not sure when the best time to use it would be. For instance, he said:

> Maybe later, instead of using it at the end as a sum up, use it at the beginning maybe introducing tonicity later on and osmosis. I don't know. I might do it again after the EOCT, just as a review, and something fun and something different, and then eventually, try to work in to where it's a, maybe, where it's a before I actually teach hypo-, hyper-, and isotonic. Maybe do it as a preview. I don't know how that'll work cause there is a lot of terminology in there, but maybe they can learn what hyper-, hypo- , and iso- is just by going through the program. But, I definitely plan on using it again. (Mr. Palmer, Interview #2)

Ms. Franklin said she would not use it for review as she did this time. Because of the pressure of their upcoming midterm, she thought she did not get the most out of the program.

She wanted to use it as an activity within the unit of osmosis next time, not separately after the unit.

On the other hand, Mr. Lennon used the students' responses for getting ideas for their future teaching. Mr. Lennon had planned to grade the students' responses based on an informal rubric such as did they complete the whole thing? As far as the range, how many attempts did it take them to understand? Were their comments specific enough? Did they use scientific terms? Did they incorporate that into their answer? The rubric in his thinking at the beginning of the lesson was not focused on understanding of the basic concepts; rather, it was related to overall participation in the activity and the skill to write like a scientist.

Mr. Lennon saved the HTML file of the students' responses on his flash drive when they finished the program. But, he did not actually grade their responses. He looked through them, and he described his feeling about the students' responses like this, "I guess one of my issues were that some of the kids were a little bit too general in their statements that they just say, water left the blood vessel. Well, I am more looking at using the scientific term that you have like hypotonic, hypertonic, and isotonic solution." He expected the responses to be more professional writing, like a scientific report, and he wanted to look at how the students used the scientific terms in their responses. However, a few students were not as specific as he wanted them to be. For this reason, he reflected on how he should have asked the students to discuss their problem solving approaches prior to do the activity as a way to simulate them to be ready to write their answer like scientists. He added on the reflection that at that time, "it was the beginning of semester so we were going to work on how to write data down and how to be specific throughout the semester."

Mr. Lennon planned to use the material at the end of the semester. By using it later, he wanted to make sure that the students had done a better job of writing up a proper lab report before using the material. If he used it in the middle of the semester, he thought he would need to spend a great deal of time on what he expects as far as what they write or type. If he did that, he thought that he would learn a lot about the students' learning.

Ms. Mitchell and Mr. Watts did actually grade the students' responses. Ms. Thorn (Ms. Mitchell's mentor teacher) charged Ms. Mitchell with grading of the activity. Ms. Mitchell basically graded the responses based on whether they had completed them or not. Then she read the answer for one single question, why is the water moving across the vessel? and gave the students credit for this one response. She believed that she could evaluate if students understood the concept of osmosis through this question.

For the question that she examined during grading, Ms. Mitchell said about 25 % of the students answered in this way: "it's like hypotonic inside the vessel and so water's moving out because it's hypertonic outside of the vessel (Ms. Mitchell, Interview #3)." She said a lot of them who didn't quite understand the concept described it more in terms of the density of water than the concentration of ions: "Like there is a higher density of water molecules." Some of them didn't really understand the mechanism, which was to maintain homeostasis. There were a number of those responses as well. There were two or three responses that said why the water was moving out was because that was where the blood was flowing. The main thing that she noticed in their responses for understanding osmosis was that they were thinking that it needed to move outside the vessel because there was a lower concentration of water to ions.

So, she only graded the responses based on completion and the answer to one question. What she mostly considered was completion, so half of them got 20 points out at the possible 20, and the lowest grade she gave was a 17 because of overall incomplete responses to and the answer to that one question. She said she would use the final summary question as well next time.

Like Ms. Mitchell, Mr. Watts had a similar standard for grading the students' responses. He planned to see if they were thorough. His assessment of this characteristic of the students work was based in a number of questions including: Did they make a solid effort on every question? Did they answer everything? When it asked you to explain, did you actually explain or just say yes or no? In addition, he planned to pick out two or three that he thought were critical to demonstrate that they understood what they were doing. But he was not going to grade too many of them in great depth for two reasons. One was the time limitation. At that time, his school was coming up to the end of grading period, so he honestly said, he would not have time to sit down and to carefully go through all of it.

The other reason for why Mr. Watts decided not to grade the responses in detail was that students lacked the writing skill to effectively express what they know. When sharing with me his impressions of how they did in their responses, he stated that the students, 9th graders, needed a lot of direction and he should have provided it. For example, he reported that some of their answers were well-written in two or three paragraphs that reflected a very solid grasp of the process. But, others (that he knew were very smart and had the same insight) did not write what they understood on their responses. He thought they just hurried through it.

Mr. Watts actually counted the responses as a small quiz. The majority, he believed, made a serious attempt to answer every question. Again, he knew they had more in them than they showed. So, he basically gave them a 10 out of 10 points if they made an attempt to answer everything, even if every answer was not absolutely right. Some of them who went into a great depth got extra credit: He gave them 12 points out of 10. Five or six out of 32 students got the extra credit because their answers were, in his judgment, sufficiently thorough.

Although Ms. Mitchell and Mr. Watts did actually grade the students' responses, Mr. Watts's utilization of the responses was like Mr. Lennon's. He used the responses as a tool to learn the students' weakness in writing. On the other hand, Ms. Mitchell spent more time reflecting on her performance as a teacher than the other teachers did. For example, she remarked, "I did a better job teaching it the second time and they [the students] were 'able to do it, work through it easier and also reminding them what hypo- , hyper- , and iso- really helped them." Also, based on the grading, she reflected on her teaching tasks, especially on how to help the students understand better. "But, I think I would have a little bit- spent a little bit more time allowing students to work out which way is the water going so giving them a few problems and saying, okay, this is the cell, only water can move out, and then which way is it going to move and why and giving them that extra practice before they actually have to do Clark. I think it would have kind of solidified their understanding that osmosis has to do with the concentrations of ions and making that, those two sides of the membrane equal concentrations" (Ms. Mitchell, Interview #3).

Ms. Mitchell planned to use the material within the unit that covers diffusion and osmosis. She stated, "It's just a matter of making sure that they have some grasp of osmosis prior to doing Clark." After talking more about cells and cell membranes and what is allowed in and what is allowed out, the students could understand better. She wanted to review osmosis prior to doing the Clark so that the students would already have an idea in their head that this is dealing with osmosis and that something about this case had to do with an imbalance of solutes in the blood in Clark. Also, she thought she needed to prepare the students so that they could answer more completely in terms of the data that they got from the program and in terms of the movement of ions in the differential concentrations.

As described earlier, Mr. Watts had hoped his students would express their understandings of what happened in greater depth than they did. He felt confident about the students' ability to understand what they did in *Clinical Clark*, and stated, "I mean, they understood, they got it. I think they were understanding what was going on, and why the treatment helped, [but] they had trouble expressing it because the game is visual, it's not verbal." Related to their nonspecific writing, he reflected that he had just "turned the students loose on it" without much introduction at all. He said he would be more direct about his expectations for the students next time. He also considered how he would present it next time to get the students to be more verbal about what happened and why.

Summary

The teachers evaluated the instructional sessions using *Clinical Clark* as "great" with regard to students' engagement and excitement. They thought the students' role as veterinarians in the program made them more engaged. The computer environment that allowed them to manipulate the program was another factor that kept the students focused on the activity. However, the 3-D models and animation aspect of the program was not mentioned as a factor related to the students' learning.

With regard to students' learning, the teachers thought the use of the material somewhat helped to reinforce the students' osmosis-related knowledge. Also, they all agreed that this curriculum was a meaningful experience for their students as the case was a real life example of osmosis and the students were exposed to Clark's situation. However, they were not sure about students' understanding of the big picture of the case study, which they wanted the students to learn through the activity. From the analysis of their interviews about the students' learning there does not seem to be any doubt or critical questioning of the source of problems. Also, the teachers' reflection on the lesson did not seem to lead to further or deeper questioning of their practice, nor did these teachers use the perspectives of students in reflecting on this issue.

For an assessment, even though the teachers had planned informal criteria to grade the students' responses, most teachers did not use the students' responses as an assessment tool, and those who did mostly focused on completion, not correctness. In part, the responses were used as a formative assessment tool to inform their teaching and check students' current learning. Many of the reasons for not grading the responses were related to other factors such as lack of time.

Given their positive evaluation of the class, all the teachers expressed their willingness to use the curriculum material in the future. Most of them would like to use the material in the unit on osmosis again. Two teachers were open to other possibilities regarding when and how to use it next time.

Overall, the comments in the teachers were largely descriptive statements about what happened in the lesson. In addition, there were some brief evaluative comments about how successful the lesson was. The teachers' reflection level was affected by the degree of their interactivity with students during the class and reviews of students' responses after class. However, there was no evidence of critical reflection in which teachers analyzed classroom events and their own feelings in depth. Only one teacher, Ms. Mitchell who is the least experienced teacher, reflected on her teaching practice and said that next time she would keep in mind what they had learned from the class. A deeper understanding of their own practice with respect to strength and weaknesses in a student-centered computer environment was not evident based on the analysis of data from their post active reflection.

CHAPTER 5

DISCUSSION AND IMPLICATIONS

Summary of the Study and Discussion

This study examined science teachers' experiences using a new curricular module about osmosis during the three stages of teachers' activity: planning, implementation, and reflection. I started this study with the belief that using these curriculum materials in class would be beneficial for both teachers and students; that these materials would be a good tool for teachers seeking an inquiry activity, and that they would improve the students' learning. Specifically, I focused this research project on developing an understanding of teachers' perspectives about the instructional uses of the new curriculum materials described in this study.

As has been stated earlier, the research proceeded in a series of stages or steps. At the beginning of the research project, the researchers introduced the new curriculum materials to a selected group of biology teachers. The new osmosis module was an interactive case study called *Clinical Clark* and was developed by a UGA research team funded by a grant from the *Science Education Partnership Award* program at the NIH. After that initial introduction of the module to the teachers, I then conducted this project by examining how these teachers planned, taught, and reflected on their teaching with the new curriculum module. Interviews and observations were the main sources of data for the research. Six science teachers and two student teachers from five local high schools participated in this research project. These teachers' practices were explored through interviews and classroom observations. The technology used in the schools, such as computers and networks, varied, as did the characteristics of the students in each classroom.

At the outset of the data collection a pre-interview was conducted with the teachers in order to know what factors they considered when deciding to use new curriculum materials. It became clear that one important factor in their decision-making was the teachers' prior instructional experiences with osmosis. However, the analysis of interview data showed that the prior instructional experience for teachers participating in this study was almost the same. A further analysis of the pre-interview data revealed that the teachers had many common prior experiences in teaching osmosis. For instance, they usually introduced the concepts to the students by lecturing within a curricular unit whose primary topics were the cell and its structure. Second, the teachers commonly reported that they explained that the cell membrane is semipermeable and thus allowed for differential movement of molecules into or out of the cell through the cell membrane. Third, the teachers reported that after introducing the cell structure and function, they drew representations such as a cell in a beaker and then explained the direction of the water's movement through the cell membrane according to different concentrations of solutes in the solutions on either side of the membrane. After teaching osmosis and tonicity-related terminology, the teachers reported that they did what are commonly referred to as "the egg lab" or "the potato lab" to demonstrate how osmosis occurs when solute concentrations inside and outside the cell are changed. The teachers reported that they were satisfied with their prior teaching of osmosis. In evaluating the students' learning, they believed that most of the students understood the concept of osmosis, but they felt the students had difficulties using the terminology such as hypertonic, isotonic, and hypotonic.

Concerning the teachers' beliefs about science curricular, they were in general agreement that there is no one perfect curriculum. This internal belief can explain why they were open-minded about using new curriculum materials. Regardless of the length of their teaching experience, all six teachers were willing to accept new ideas if they could improve their teaching and their students' learning.

The instructional materials based in highly advanced technology has been introduced throughout all subject curricular. In particular, science curriculum materials that incorporate significant innovations in technology have been actively developed by science curriculum developers because the technology can be used in many ways as an integral part of the science curriculum to meet the needs of diverse learners. For example, it can be introduced into the classroom as exciting curricula based on real-world problems; provide scaffolds and tools to enhance learning through visualization; and give students and teachers more opportunities for feedback, reflection, and revision. In particular, the interactive 3-D models used in this study allow students to explore and interact, rather than simply watching animations made and presented in the form of movies. Nevertheless, increases in science specific-software do not ensure the actual uses of that software in science classrooms.

As the study of teachers' decision-making regarding curriculum continued, the next factor considered was related to technology-based curriculum material. To investigate the issue of using a technology-based curriculum in science classes, the teachers' perspectives on using technology were examined. First, when the teachers discussed their beliefs about technology and using technology, they each said that they were seeing many benefits from using technology in teaching. The teachers viewed technology as an additional resource for improving students' learning. The technologies teachers usually used in class were a projector to show their

PowerPoint presentations or short video clips to the students and computers to allow the students to search for information for class projects. Three teachers reported they often use the computer when they look for better curriculum materials and if they find something better than the materials they were using, they use it. However, they rarely used science-content-specific software. Two of the six teachers had used online labs to allow the students to use the technology in the past. Their positive dispositions toward using technology for teaching were not science specific nor did they lead to frequent use of the technology.

The participating teachers' perspective of teaching in general and of science teaching specifically affected their selection of curriculum materials. These perspectives, as implemented by each individual teacher, guided the whole teaching process about which teachers explicitly or implicitly make decisions (Borko & Livingston, 1989; Clark & Yinger, 1979, 1987; Ethell & McMeniman, 2000; Aikenhead, 1984; Park & Oliver, 2008). Along this line, analysis of the collected data showed that if teachers felt that using technology-based curriculum materials fits with their teaching philosophy, they would use it in the classroom. When the participating teachers were asked an open-ended question about their thoughts on teaching and teaching science, they each stated their own perspectives of teaching science in terms of what they ultimately aimed to accomplish in their classroom and what they regarded as a good example. Because Mr. Palmer and Mr. Watt thought biology is abstract to students, their science teaching was aimed to help the students to effectively become knowledgeable about the abstract content. Mr. Hall and Ms. Thorn emphasized the students' doing activities in their science teaching. They said they usually employed a variety of teaching strategies to ensure that the students experienced hands-on learning. In contrast, Mr. Lennon emphasized critical thinking through his teaching. However, all the teachers had one belief in common: they thought student-centered teaching was good teaching of science. Beliefs about teaching, beliefs about science, or beliefs about students do not work in isolation from one another but intertwine with each other, so the teachers' perspective on teaching and science teaching seemed to affect their decision making on the selection of curriculum material.

Remillard (2005) identified factors that may influence teachers' use of instructional materials in the teacher-curriculum relationship framework. The framework she proposed highlights the interaction between the teacher and instructional resources used to enact the curriculum. She discussed a variety of factors that function as mediators of a teacher's enactment of curriculum including: pedagogical content knowledge, subject matter knowledge, belief/goals/experience, perception of curriculum, perceptions of students, tolerance for discomfort, and identity as teachers' individual characteristics affecting the relationship. In line with this framework, I directly asked teachers to explain their rationale for choosing curriculum materials. I grouped the responses that emerged from the data analysis into four categories. Three teachers, all of whom teach in public schools, reported that state standards are an important criterion in selecting curriculum materials. Interestingly, but not surprisingly, the two teachers who teach in private schools did not list state standards as one of their criteria. Three of the four teachers taught biology courses in which the students had to take an end-of-course test, and these three teachers identified the standards as the most important factor when choosing specific curriculum material. The next criterion the teachers often mentioned was their students. The perceptions of the students that the teachers had accumulated through the semester positively affected their decision-making on using curriculum material with respect to the students' ability to perform the learning task encapsulated in the curricular material and the students' engagement in doing the activity through the curriculum materials. The last aspect that the teachers considered in selecting curriculum material was the science related-characteristics of the curriculum material. They took into account subject specific considerations such as how the material visually presented biological concepts or processes; how much science reality is reflected in the material; and how much science relates the material to their students' daily lives.

Another important factor in the teachers' selection of curriculum materials was each teacher's educational philosophy: their beliefs about what good science teaching is and their perception of their students. Of course, three of four public school teachers are required to follow the State standards, but they did not consider these standards to be related to their philosophy rather regarded them as a requirement from their schools. With respect to the teachers' thoughts about technology, they all expressed a positive effect of using technology in class, but none of the teachers believed that technology by itself increased student learning. That belief as expressed by the teachers seems to mean that it was apparent that these teachers saw technology as an additional tool that assist teaching and learning, not as an essential tool for the creation of a better teaching and learning classroom. That belief also explained why the teachers did not use all of the technology embedded programs that were available to them. I concluded that teachers want technology to provide challenging and exciting tasks that make students engaged in class, but they also will maintain their role as decision maker about what aspects of the curricula get enacted in the classroom.

In the interactive stage, the teachers' implementation of the new curriculum material was similar, particularly with respect to their adoption methods. They all offloaded much of the responsibility for the content to the curriculum material, *Clinical Clark*, regardless of their school type (public/private), the type of class (honors/regular), the students' abilities, and the schools' computers. The teachers, for example, generally at the beginning of class, reviewed diffusion and osmosis before introducing that day's activity, *Clinical Clark*. After that, the next step in the instructional sequence was for the students to do the program. During the working time, all of the teachers walked around the classroom and talked with the students individually although the degree of interaction with students was highly variable. At the end of class, the teachers summarized Clark's case. The reasons that all the teachers offloaded the curriculum material can be explained by the features of *Clinical Clark*, which are based on technology and required the active participation of the students. As a result, *Clinical Clark* allowed the teachers to spend the greater part of the class letting their students become invested in the activity. Also, it allowed them the time to interact with the students individually while the students were doing the activity.

However, there were great differences in the points they emphasized to students during the discussion. The participating teachers emphasized some parts of the *Clinical Clark* activity and led the discussion with their students in slightly different ways. Although all the teachers mentioned that the curriculum material would help the students develop thinking skills at the whole organism level, not all the teachers placed emphasis on thinking skills as they led the discussion with their students. Whether the discussion happened while the students were engaged in the program mostly depended on the teachers' perception of their students' abilities. Some of the teachers who perceived that the students needed to learn basic concepts focused more on the learning of osmosis itself rather than the whole process of Clark's case. There were also some gaps in the teachers' actual implementation of the material in terms of the ways they described their understanding of the curriculum material and how they connected those descriptions to their use of the curriculum materials. For example, while they emphasized the value of student thinking, the teachers actually focused more on the learning of concepts or on the degree to which students really understand.

In the post-active stage, the teachers reflected on their teaching and students' learning with the use of *Clinical Clark*. In evaluating the class using the material, the teachers stated that it did somewhat help to reinforce osmosis-related knowledge of the students. Also, they all agreed that this module was a meaningful experience for their students as the case was real life example of osmosis and they were satisfied with the students' exposure to the medical condition affecting Clark the calf. Overall, the comments from the teachers were largely descriptive statements about what happened during the lesson. The teachers' reflection level was affected by the degree of their interactivity with students during the class and reviews of students' responses after class.

Teachers who engage in reflection may adapt curriculum materials in the sense that they go beyond simply following the prescribed curriculum in using the resources to facilitate the teaching and learning practices they envision (Choppin, 2011). Choppin's findings support that the teachers justified and modified their own instructional practices in terms of the sense-making of students' learning that they gained by reflecting on the class. In the present study, however, there was no evidence of critical reflection. Specifically this evidence would have had to provide resolution of incidents where teachers analyze classroom events and their own feelings in depth and draw conclusions for future actions. The data analysis did not provide this evidence.

Implications

Many studies have raised questions about teachers' uses of curriculum materials and have pointed out that there is a need for more research to inform practice. To address teachers' perspectives empirically, this study examined teachers' experiences with a specific new curriculum material based on the use of high quality interactive 3-D models and animations. The findings from this study offered several practical implications for science curriculum developers, science teacher educators and science teachers.

Considering that the next generation of students will be more technology based, curriculum developers need todesign science curriculum materials that meet the needs of a learning environment utilizing technology. The findings of this study inform science curriculum developers in several ways. First, inquiry activities should be included in curriculum materials. All six science teachers involved in the study chose to use the software in the class as an inquiry activity. As such the *Clinical Clark* activity was used as an inquiry activity for students to solve a medical problem after extensive teaching about osmosis. Their choices indicated their perception of a connection between active learning, scientific inquiry and engagement by doing the activity. The teachers also believed the case story and role playing helped increase students' opportunity for active engagement in the lesson using technology to promote thinking instead of passively watching computer-based presentations. Their thoughts imply the need for an inquiry context for designers of technology-based instructional materials.

Second, explicating both the science content of the materials and the task features in curriculum materials may help teachers evaluate and select materials that support their perspectives of good science teaching, and potentially lead them to use materials in ways consistent with those perspectives. More comprehensive materials, which include more facets of content, instructional approaches, links to standards, and assessments, may also attract teachers to use the materials.

The findings of the study show that all teachers offloaded the curriculum materials because they had confidence in the content of the curriculum material as an inquiry activity including a real life example, and because they were certain that the curriculum materials would improve their students' knowledge. In this case, offloading the curriculum material had some benefits for teaching and learning. For instance, the offloading led to opportunities for individual in-depth discussions between teacher and students. However, not all teachers, even teachers who highly valued the module, would be willing to spend an entire period doing this activity using technology. With regard to the variability of instructional context, if teachers encounter some unexpected inhibitors such as time, tests, technology issues, or low ability of students, they might not continue to use this material. Building in options for teachers to extract some part of the program according to their circumstance or needs may help teachers overcome the constraints in using the software. From there, teachers can be supported in their adaptation and improvisation of available materials.

This study also has implications for science teacher educators. The process of using technology-based curriculum materials is mediated by teachers' knowledge, beliefs, and dispositions. Teachers require substantial support in learning to use new curriculum materials. They need to know about the content, goals, approaches, access to the curriculum materials so that they could get benefits from for their teaching and students' learning. Science teacher educators should give in-service teachers opportunities to explore and examine new curriculum materials, and make their interpretations and decisions as part of teacher professional development. Professional development opportunities and workshops for in-service teachers are important with regard to using technology for teaching. Such opportunities allow teachers to stay aware of what is going on in science education and update or reinforce their knowledge about using new technologies.

In particular, new teachers are hungry for curriculum materials and guidance. The combination of a lack of experience and lack of exposure to curriculum materials during teacher education as well as the feeling of being overwhelmed that novice teachers experience may make it difficult for teachers to adopt new technology-based curriculum materials. Therefore, in teacher preparation programs, introductions to new curriculum materials and opportunities to discuss these materials can help them think more about the subject matter as well as the instructional decisions they make regarding students learning. This research suggests that this activity will help preservice teachers utilize their resources thoughtfully.

The findings of this study also suggest that teachers should reflect on their classroom practices in order to incorporate technology and inquiry into their teaching more effectively. In the reflection, teachers analyze their experiences and reflect on their practices. By doing so, they can see the effectiveness of technology on students' learning and reflect on and modify their practices. As emphasized by other research (such as: Park & Oliver, 2008) reflective practice can help teachers improve their knowledge of pedagogy and their knowledge of students. Thus, these teachers should have opportunities to reflect on their teaching and share their experiences with other peer teachers.

Directions for Future Research

This study was conducted in three public schools and one private school in several small cities in Georgia. The participating teachers are very enthusiastic about using new curriculum materials and highly value students' active learning. It is possible that cultural and environmental factors and the teachers' characteristics in that region could have affected the results of the study. The inferences I have drawn from the data must be considered in terms of the teachers' backgrounds. However, as a case study, the goal was not to generalize findings to other situations but rather to build explanatory models that other researchers or teacher educators could use to help explain teachers' experiences with new technology-based curriculum material in their teaching. Future research could include studying a variety of teachers from different schools with different primary instructional materials and different teacher philosophy backgrounds.

A longitudinal study could be conducted, looking for shifts in how teachers select and implement curriculum materials including technology. Longitudinal studies tend to be expensive and difficult to manage; a mixed methods approach, using quantitative instruments and supporting classroom observations and interviews, could provide manageable data collection and analysis possibilities. Such a study could also enrich our understanding about the relationship between teachers and curriculum materials within contexts that include technology in teaching.

As I set the stage for designing the current research, I focused on teachers' perspectives on using new technology-based curriculum materials. In doing so, my investigation was based on the teachers' comments regarding the effectiveness of the curriculum materials; students' thinking and understanding was not the primary purpose of this study. Future research on students' scientific thinking and learning in classes using new technological curriculum materials can give more complete explanations such as the influence of the curriculum materials on students' learning.

Classrooms today are radically different from classrooms of 100 years ago, but the challenge still exists to integrate new and different technologies. The tools have changed from chalk to SMART Board pens and from textbooks to online material, but what is the reality? This study explored six teachers' experiences with an inquiry-based module, *Clinical Clark*. However, the teacher was still the definitive force for instruction in the classroom. The analysis of the statements from their thoughts about using the curriculum module indicated the interaction between the teacher and the student determines the focus and outcome of classroom instruction.

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APPENDIX A

WORD DOCUMENTS AND PDF FILES PROVIDED TO TEACHERS

Executive Summary

Osmosis Case Study

This highly interactive, inquiry-based case study format was created to engage learners from different cultural and academic backgrounds in the investigation of biological processes that are fundamental to the understanding of biology and its associated disciplines. During this case study, students will explore the concept of osmosis from multiple angles, using deductive and inductive reasoning to construct and test hypothesis, take measurements, make observations and inferences. During this 90-minute case study, your students will be exposed to scientifically accurate and rigorous activities, with one over-arching purpose – to engage them in the scientific habits of mind.

What is hyponatremia?

Simply stated, hyponatremia is a condition in which sodium levels in the blood are abnormally low. Sodium plays many important roles in the body, including helping to regulate body fluid balance, supporting the function of nerves and muscles, and maintaining normal blood pressure. When sodium levels are low in the blood, water leaves the bloodstream, and enters the tissues, causing them to swell. Because the brain is encased within the bony skull, swelling of the brain tissue results in an increase in intracranial pressure. This increase in intracranial pressure causes neurons to fire sporadically, leading to seizures, and, if left uncorrected, coma and death. Hyponatremia occurs most often in people who have ingested large volumes of water after a period of strenuous exercise, during which they have lost significant amounts of sodium in their sweat. In this case, hyponatremia developed in Clark, a young calf that was given excessive amounts of water by its owner in an effort to counteract the effects of diarrhea. Unbeknownst to the owner, diarrhea results in the loss of sodium ions from the body.

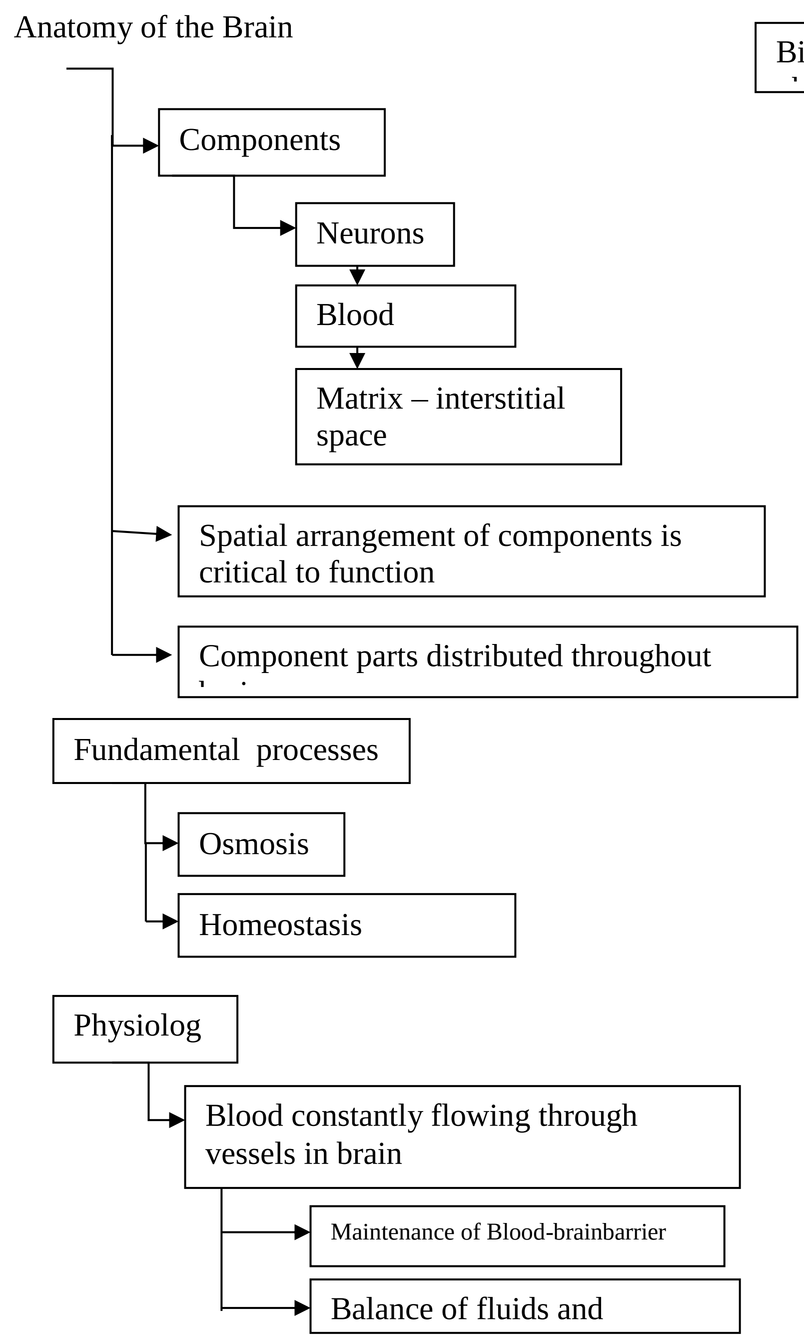
What will students do?

In this case study, students take the role of a veterinarian. Using a guided inquiry approach, students will measure concentrations of electrolytes in the blood and brain tissue, monitor the firing rate of neurons, and measure pressures in the blood and brain tissue. Having taken these measurements, they will be given three treatment options: hypotonic, isotonic and hypertonic saline solutions that can be given IV. After predicting which treatment will be most effective, they will then administer the treatments, and evaluate the results. The case study ends with application questions that will challenge your students to apply the concepts they have learned.

What will students learn?

Students will learn and understand how to apply fundamental concepts of osmosis by comparing the effects of thethree different treatment options. In doing so, they will be exposed to the concepts of tonicity, concentration, osmosis, diffusion, pressure, and homeostasis. Students will observe, examine, and then infer how the different concentrations of saline alter net water movement in Clark’s tissues, and their effects on seizure activity.

Provided is a reference sheet containing answers to all of the questions that your students will be addressing in this case study. We hope that you and your students enjoy this experience!



Biology content learning

Students will learn the names of the parts of the brain and be able to visually recognize them.
Students will learn that the parts of the brain are distributed throughout the cranial space.
Students will learn that excess fluid in the braincauses pressure to increase.
Students will learn that excess pressure in the brain can cause a disruption of nervous function.

Students will learn the chemical nature of the processes of osmosis and maintenance of homeostasis.
Students will learn to apply this knowledge to the case of hyponatremia.

Students will learn that there is a constant exchange of fluids and minerals into and out of the blood –as dictated by osmosis and other chemical properties.
Students will learn that biological systems work in conjunction with chemical properties for the maintenance of homeostasis.

GPS Objectives covered by Hyponatremia Case Study

Content Objectives

SB1. Students will analyze the nature of the relationships between structures and functions in living cells.

a. Explain the role of cell organelles for both prokaryotic and eukaryotic cells, including the cell membrane, in maintaining homeostasis and cell reproduction.

d. Explain the impact of water on life processes (i.e., osmosis, diffusion).

Characteristics of science objectives

SCSh1. Students will evaluate the importance of curiosity, honesty, openness, and skepticism in science.

b. Recognize that different explanations often can be given for the same evidence.

SCSh3. Students will identify and investigate problems scientifically.

a. Suggest reasonable hypotheses for identified problems.

b. Develop procedures for solving scientific problems

c. Collect, organize and record appropriate data.

e. Develop reasonable conclusions based on data collected.

SCSh6. Students will communicate scientific investigations and information

SCSh7. Students analyze how scientific knowledge is developed.

SCSh8. Students will understand important features of the process of scientific inquiry.

APPENDIX B

INTERVIEW QUESTIONS

Backgrounds

- Tell me about your science teaching experience (followup: number of years, subjects taught).
- Could you tell me about the classes you are teaching in this semester? How about the students in your classes?
- Could you describe what your science classes look like? What are the characteristics of your science teaching?
- What do you think makes science (what you are teaching) a difficult subject to learn for many students?
- How do you think your students learn science best?

RQ1. What influences teachers' decision making with regard to his/her instructional use of the 3-D animation curriculum materials?

Interview 1 (before implementing the 3-D animation curriculum material)

- What do you think might work or might not work with this 3-D animation-based curriculum material?
- Tell me about when and how you are going to use this curriculum material.
- How do you envision doing this during the specific lesson?
- How do you envision helping students understand specific content (osmosis, homeostasis) when using this materials?
- What do you envision students doing when using these materials?
- How long do you think this activity will take?
- What part do you think might be hard for students to understand in this 3-D animation curriculum materials?
- What will student learn from this session? What concepts will they learn? What processes will students learn?
- How will you know if students understand the specific content?
- What aspect of your knowledge of students was most important in planning and implementing the lesson with the 3-D animation curriculum materials?

RQ 2. What deviations do teachers report from their normal planning and teaching routines when adopting the 3-D animation curriculum materials?

- Tell me how you plan for a lesson?
- What materials do you generally have available?
- Is there a specific time? Place?
- Is this scheduled time the only time planning occurs? Tell me about other times you plan or think about your lesson?
- How much time during the school day do you give to planning?
- What do you take into account when planning?
- How much of this goes into writing?
- Do you have a different plan for every class?
- How many lessons ahead do you typically plan?
- Tell me about how you plan for this unit or theme?
- Do you have a yearly plan?
- Once you have planned your lesson, does it ever change? Why or why not?
- Over the years have you seen a change in your planning practices?

RQ 3. How do teachers implement 3-D animation curriculum materials?

How are teachers' instructional actions a reflection of the intentions expressed in their planning for that instruction?

How do teachers adjust their instructional actions for the specific classroom context when using the new curriculum based on 3-D animations?

Class Observation

- While teaching a lesson, does the teacher stick to his/her original plans?
- If he/she changes, what promotes the change?
- How he/she interact with students?

RQ 4. How does the self-evaluation of the lesson affect future planning with regard to the use of the specific animation or other related animations?

Interview 2 (after implementing the 3-D animation curriculum material)

- How do you think the lesson went? Tell me about the lesson.
- What would you change about this lesson?
- Tell me more about the situation (what I observed in class).
- What do you think students learned in this lesson?
- What do you think students learned by using the 3-D animation?
- What was the most frequent question from the students?
- What kind of explanations did you give to students?
- How did the 3-D animation curriculum materials help them learn this?
- How does the use of the 3-D animation curriculum materials compare to other instructional sessions you have conducted with these students?
- How would you use these 3-D animation curriculum materials for future classes?
- Let me know how the next class is going on in detail. How do these evaluations affect future lessons of the same class; of another class of the same grade level or lesson content or; of the same content area to be taught later in the year or next year?

APPENDIX C

OBSERVATION AND INTERVIEW DATES

Teacher	Date	Class	Data Source
Ms. Franklin*	9/24/2010 12/13/2010	 Biology (B) 14/21/23	Introductory meeting Observation Interview
Mr. Palmer*	12/1/2010 12/15/2010	 Honors Biology(B) 26	Introductory meeting Observation Interview
Mr. Lennon	1/28/2011 2/4/2011	Zoology(B) 28	Observation Interview Interview
Mr. Watts	2/8/2011 2/9/2011 3/3/2011	Honors Biology 15/15	Interview Observation Interview
Ms. Thorn Ms. Rhodes*	2/8/2011 2/16,17,18/2011 2/16, 2/17 3/3/2011	Biology 5/16/11	Interview Observation Interview
Mr. Hall* & Ms. Mitchell*	11/15/2010 2/22/2011 2/23/2011 4/21/2011	Biology(B) 24/12	Introductory meeting Interview Observation Interview

*: teachers who have not used the animation beta version (animation +worksheet) before.

(B): Block Schedule.

APPENDIX D

The Worksheet Distributed by Mr. Palmer

Students:

1. Sign up for a lap top or a net book in groups of two's!
2. Go to the V: Drive ---Science---Yauck----Outbox
3. Click on Clinical Clark
4. One of the group members register your name

CLINICAL CLARK

You are a Veterinarian who is called into check on a sick calf! The calf has had diarrhea and has been treated for dehydration. Now the calf seems to be sicker. He is lying on the ground unresponsive and is having seizures! You must navigate through readings and tests to determine what is the cause of Clark's problems and administer the right treatments to nurse him back to health!

When beginning Clinical Clark, Read and navigate through the tutorial. It will tell you all controls to use as well as how to take the readings necessary to save Clark!

APPENDIX E

The Worksheet Distributed by Ms. Franklin

Osmosis Simulation

Review diffusion and osmosis

Before you begin . . . google:

1. Epilepsy – write a short description

2. Cerebral edema – write a short description

Open the program - on Clark the cow (Saving Clark)

1. Login – first and last name and follow instructions
2. Do the introduction to the parts of the brain
3. Do the tutorial
4. Click on the chart when finished with the tutorial
5. Double click each part of the brain and hold to get readings
6. Click on chart and up load
7. Interpret, check answers, answer questions, continue with instructions

Answer these questions:

1. Why is water moving across a vessel?

2. What effect does the net movement of water have on pressure in the matrix?

3. What is the relationship between water movement, matrix pressure an d neuron firing rate?

Go to Diagnosis

Follow instructions until you have completed treatment, treatment summary, case summary.

1. What standard does this activity cover? Write it out not just the number and letter – see book

2. How is knowledge about osmosis used in the real world.

APPENDIX F

Reflective Level with Examples from Data

	Level of Reflection			
Category	Description or Recall	Descriptive Reflection	Dialogic Reflection	Critical Reflection
Students' engagement	I felt like they were very focused and intense.(Al) They [students] did a good job, better than I did. They are always better at technology than I am.(Munro) They[students] were amazed by how quickly the students were able to navigate the program.(Anna) I continue to be impressed by how comfortable they are with the whole technology. (Richard)	They seemed to be more empathetic with that situation. I felt like it had them more focused on their performance. (Matt) They have empathy for a live organism is I think important. That pleased me. That they were pleased with the change of pace and they jumped right into it without any hesitation. (Richard) I think the fact that it's on the computer is fabulous and I think the kids really got into it, they were excited, the role of the visualization in getting the students to see the importance of a disorder in the body. (Anna) if it looks like it's not of high quality,		

		it's going to be boring to them and I could not get their attention, so [with] the high quality animation so they were, 'Oh yeah'(Munro)		
Students' Learning	Students got more some scientific terminology from using Clark, and also reinforced their idea of tonicity. (Al) Hopefully, it helped with that—maybe just to grasp a little bit better how everything functions together inside the body. (Munro) A few of the kids were little bit more confused because they were struggling with some of bigger questions, but a lot of them really took a lot from it. (Anna)	I think the greatest misconceptions was that they were thinking that it was because there was a lower concentration outside of the cell, outside vessel, that's why it needed to move outside the vessel because there was a lower concentration of water to ions. So that was the main thing that I noticed in their responses for understanding osmosis. I think their ability to really understand why the water moves, to really notice that the water was moving outside of the blood vessel, determined a lot how well we reviewed osmosis before they went into the program. (Ashley)	All the students understood that tonicity is relative and changes in tonicity they struggled with answering some of the bigger questions asking for a treatment summary and case summary. The extra recapping activity by the teacher, like whole group discussion after finishing the activity, was necessary for the students to conceptualize the activity in their minds. (Matt) In talking with a couple of students, I remember being very impressed by their level of understanding. They were able to answer my leading questions, "What would happen if you did this? Why did this happen? And so forth. [after reading students' responses]I learned, I need to be more	

			specific about the insight and depth, they need to demonstrate their insight in a very concrete way in their answers. (Richard)	
Planning for future classes	Maybe later, instead of using it at the end as a sum up, use it at the beginning maybe introducing tonicity later on and osmosis. I don't know… But, I definitely plan on using it again. (Al) Next year, I would not use it for review. I would use it as part of the lesson. (Munro) And the kids enjoyed it very much, but I will be using those in the future, definitely. (Albert)		I think I would have a little bit- spent a little bit more time allowing students to work out which way is the water going so giving them a few problems and saying, okay, this is the cell, only water can move out, and then which way is it going to move and why and giving them that extra practice before they actually have to do Clark. I think it would have kind of solidified their understanding that osmosis has to do with the concentrations of ions and making that, those two sides of the membrane equal concentrations. The other thing I would have done is just kind of prepared them for answering the questions more completely, so that means like, you know, saying, it is because homeostasis is why it	

			occurred is not good enough like explaining it in terms of your data that they give you, and also in terms of the movement of ions in the differential concentrations is a more complete answer that they would get credit for because like sometimes you get, you know, because they have to get the water out, it doesn't really, I mean it's not complete understanding. So those are the two things that I would emphasize in order to have them get the most of this program. (Ashley) Most of the children that I've spoken with during the Hyponatremia exercise about what was going on and why. They seemed to understand it- they seemed to have a fairly good grasp of what was happening and why. They just did not write it very well. I am still trying to understand that. I am still trying to figure that out. Um… so maybe it's an	

			accountability issue. There's no test, no quiz, and that sort of thing. Um, I think I included a couple of questions on the test that used Clark as an example, not many, just a couple. But I think next time I will try to get them to write more effectively. (Richard)	