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Dialogic Learning and Self-Explanation in Classrooms Implementing Worked Example Instruction with Interactive Whiteboard Technology

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DIALOGIC LEARNING AND SELF-EXPLANATION IN CLASSROOMS IMPLEMENTING WORKED EXAMPLE INSTRUCTION WITH INTERACTIVE WHITEBOARD TECHNOLOGY

Dissertation

A dissertation submitted in partial fulfillment of the requirements
for the degree of Doctor of Education in the
College of Education
at the University of Kentucky

By
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Georgetown, Kentucky
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ABSTRACT OF DISSERTATION

DIALOGIC LEARNING AND SELF-EXPLANATION IN CLASSROOMS IMPLEMENTING WORKED EXAMPLE INSTRUCTION WITH INTERACTIVE WHITEBOARD TECHNOLOGY

This purpose of this study was to explore the relationship between classroom discourse and interactive pedagogies when using the interactive whiteboard (IWB) for worked example instruction. Using an embedded single case study design (Yin, 2003), the researcher examined the effect of interactive pedagogies and the differences in whole class dialogue and student self-explanation about the worked example. The sources of data included two classroom observations of teacher directed instruction and one classroom observation of student directed instruction. Each worked example presentation used a different level of interactive pedagogy as defined by Glover, et al., 2006. These included the supported didactic, interactive, and enhanced interactive.

Results of the content analysis indicated the students used more features and affordances of the IWB to facilitate conceptual development than the teacher. However, under both the teacher directed and student directed instructional methods, the IWB was used mainly for the display of the procedural steps. As a result, the IWB supported explanations that gave meaning to a set of quantitative expressions or imposed the purpose of an action rather than expand on conceptual conditions or inferences about the worked example.

Teachers' understanding of content, learning, and pedagogical practices for using the IWB is an essential element in their ability to present worked example instruction so that it facilitates student learning about the worked examples. Findings suggest implications for rethinking Activity Theory informed professional development and the need to explicitly task the teacher as a role model for students to engage with interactive display technologies for dialogic understanding.

KEYWORDS: Interactive whiteboard; Worked example instruction; Interactive pedagogy; Dialogic learning; Secondary education

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November 18, 2016
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Date

DEDICATION

In loving memory of my dad, ‘Coach’ Rick Cohn.
You are with me in spirit, every day.
Cohn Driven

Here comes the sun, and I say, it’s alright
– Beatles, Here Comes the Sun (1969)

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Chapter One

Introduction

This study derives from two distinct areas of educational research. First, research collected on worked example instruction was examined to determine the theoretical foundation and effective implementation of worked examples as an instructional device in a lesson. Second, a literature review was conducted on the interactive whiteboard (IWB) to examine 1) how the features and manipulations of the IWB content displays are used during instruction and 2) to identify the pedagogical approaches that contribute to student learning.

Although the research on worked example instruction and the IWB differ significantly from each other, the literature searches revealed several interesting areas where the intended learning purposes intersect: 1) active learning approaches to visual presentations of procedural, 2) conceptual aspects of worked example instruction, 3) collaborative whole class instruction and 4) to support students' self-explanations of content in worked examples. The aim of this study was to explore these areas to determine if and how the IWB can support student learning when used to present worked example instruction in an AP Calculus II course.

Calculus teachers often use worked examples as an instructional device to demonstrate the solution procedures of a certain problem type. Typically, the teacher follows the general format of a worked example and conveys the conceptual and procedural knowledge through visual presentation and verbal explanation to the students in a whole class learning environment.

Early research on worked example instruction was conducted before the onset of classroom technology integration as we know it today (Sweller & Cooper, 1985). Consequently, researchers utilized print-based materials, chalkboards, and dry-erase whiteboards as presentation tools. The proliferation of technology in the classroom offered new delivery mediums and presentation tools to consider when designing effective worked example instruction.

These advances in classroom technology have affected the way mathematical information is disseminated thereby potentially influencing the ways teachers educate math students. Teachers are expected to promote the implementation of technology in the context of teaching and learning mathematics in order to prepare students with the development of 21st century skills. This expectation reiterates standards established by the National Council of Teachers of Mathematics (NCTM) in 2000.[1] In their Technology Principle associated with those standards, NCTM recognizes the importance of technology as an essential component in teaching and learning mathematics stating, "it influences the mathematics that is taught and enhances students' learning" (NCTM, 2000, p. 3). Further, the Technology Principle advocates the importance of teacher training so that educators are prepared to create a "positive environment that promotes collaborate problem solving" (NCTM, 2000, p.3) whereby students themselves experience the learning event in an interactive way. Researchers have used multimedia technologies

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[1] NCTM published *Principles and Standards for School Mathematics (PSSM)* in 2000. At the time of this study, the teacher-centered principles and standards remained the same. In 2006, NCTM expanded the standards to include ways in which the student should learn the mathematical concept. The student-centered Common Core Standards were implemented in 2010. NCTM provides resources aligned with PSSM and emphasizes effective instruction that supports Common Core standards.

(Gerjets, Scheiter, & Catrambone, 2004) and computer simulated examples (Schwonke, et al., 2007) to further explore the worked example effect and provide insight into multimedia worked example presentations. Multimedia presentations combine the worked example and modality effect in a single instructional strategy to facilitate student understanding of the mathematical concepts.

Thus, teachers of mathematics are turning to instructional technologies to engage students in the lesson content in order to promote active learning of worked examples. One type of technological tool used in math classrooms for worked example presentations is the interactive whiteboard (IWB). In 2016, the National Science Board published a report on the use of the IWB as an instructional tool in elementary and secondary mathematics and science classrooms in the United States. The findings included in their *Science and engineering indicators* noted 51% of the K -12 teachers have IWBs available for them to use (National Science Board, 2016). 57% of the teachers who had access to an IWB reported using the technology tool for instructional purposes.

The IWB allows the presentation and manipulation of images, text, and video on a large touch-sensitive screen. The IWB connects to a projector that displays the content from the computer onto the screen. Special software is installed on the whiteboard and offers a variety of features or affordances using the white screen board as the interface device. As a result the IWB can be used for several types of instruction. Teachers can use the IWB as a direct didactic display of instructional material or incorporate interactive individual and interactive group work allowing students to go to the board and manipulate the display. It is also possible to add new images and animations from the

Internet or other programs to augment the existing ones in the software. Teachers have options to use ready-made materials or create their own materials and resources to support content delivery in lessons. In addition, the teachers can save the work from the display and return to the archived saved files at any time.

Current research suggests how the affordances of the IWB can facilitate an interactive learning environment for either whole group instruction or peer-to-peer interaction. Gillean, Staarman, Littleton, Mercer, and Twiner (2007) describe the IWB as an artifact that can mediate teacher and student as well as student to student interactions. Other studies emphasized the link between dialogic learning and the IWB (Hennesey, Deaney, Ruthven, & Winterbottom, 2007; Haldane, 2007; Gillean et al., 2007). The IWB, as a mediating artifact, can be used as dialogic space where verbal discourse becomes central to the learning process.

Worked Examples and IWB Instruction

Learning from worked example instruction and using the IWB as an instructional tool both involve active participation from the learner. Students using worked examples must be actively involved in the cognitive processes to determine the solution structure and rationale for choosing the appropriate procedure. The affordances of the IWB can support learning through various levels of interactivity and can be used to enhance the learning environment through use of multiple representations. Further, the research on worked examples and IWBs describes discourse as an effective approach by which students are able to make meaning and develop understanding of the instructional content. Worked example research overwhelmingly supports the importance of self-explanation when learning from worked example instruction (Atkinson, Derry, Renkl, &

Wortham, 2000; Catrambone, 1995; Chi, Bassok, Lewis, Reimann, & Glaser, 1989; Renkl, 1997). It would seem plausible that there exists a relationship between worked example self-explanations and the affordances of the IWB used to support dialogic learning. As previously mentioned, this study explored the potential relationship between worked example presentations and the affordances of the IWB to support whole-class dialogue and student self-explanation about the worked example.

Need for research

Much of the literature reviewed suggested research conducted on the IWB in whole-class settings was specific to elementary and middle school environments (Solvie, 2004; Moss, et al., 2007). While some research using the IWB is available, specifically as related to elementary classrooms, it needs be expanded to a whole class naturalistic environment in secondary classrooms. This suggestion is similar to one found in worked example research. Even though the research on worked example is extensive and offers a theoretically sound framework for the effective presentation of worked examples, Renkl & Atkinson (2003) recommended more research be conducted in real classrooms as a opposed to laboratory settings where most early worked example research was conducted.

IWB research has noted that in order to maximize the effectiveness of the IWB as a presentation tool, a pedagogical shift from teacher centered to student interactive approaches must transpire (Armstrong, et al., 2005). The IWB offers an interactive approach to pedagogy which may conflict with more traditional didactic teaching styles. Therefore, teacher training is essential to the effective use of IWBs in the classroom (Glover, et al., 2007). Teachers' understanding of content, learning, and pedagogical practices for using the IWB may also be an essential element in their ability to present worked example instruction so that it facilitates student learning about the worked examples.

The context of research for this study was a whole class settings found in an AP Calculus II class. Investigating IWB use in a naturalistic setting was to provide teachers with applicable results that can be used to understand dialogic dimensions of IWB instruction, improve methods and pedagogy and suggest direction for training in the use of the IWB as a tool for mediating learning.

Purpose

This study used an embedded single case study design (Yin, 2003) to explore differences in whole class dialogue and student self-explanation between worked example presentations and variations of interactive pedagogy used with the IWB. The central purpose was to examine the effect of the different interactive features within the interface of the IWB during worked example instruction on the quality of whole class discussion and student self-explanation.

The levels of interactive pedagogy were defined using the three classifications of interactivity with the IWB established by Glover, et al., 2007. These include the supported didactic classification, an interactive classification, and an enhanced interactive classification that are discussed in more detail in Chapter Two of this dissertation. The qualitative data were used to describe how the use of the different levels of interactivity, coupled with the use of the IWB either support or hinder whole class discussion and student self-explanation. To accomplish this goal, the research evaluated current IWB usage and examined the effect of the interactive pedagogies and IWB features on whole class dialogue and student self-explanation.

Research Questions

The research questions that framed this study are below:

1. How do teacher-led and student-led IWB visual presentation of procedural and conceptual aspects of worked example instruction affect classroom interaction
    a. In collaborative whole class instruction?
    b. In student's self-explanation of content in worked examples?
2. In what ways do different IWB features and pedagogical approach affect worked example instruction?

Following this introductory chapter, Chapter Two presents the theoretical constructs used to guide the study design and research. In addition, Chapter Two also contains an examination of the relevant literatures concerning worked example presentations and instruction using the IWB in order to provide a general framework in which to situate the study. Chapter Three presents the methodology used to conduct this study. Information on the embedded, single case-study design is included along with a description of the subjects and how they were recruited for the study. In addition, descriptions of data collection instruments, procedures, and research analyses are included in the Methodology chapter. Chapter Four presents the findings of the study. Chapter Five concludes the dissertation with a discussion of findings, implications of the study and suggestions for further research.

Chapter 2

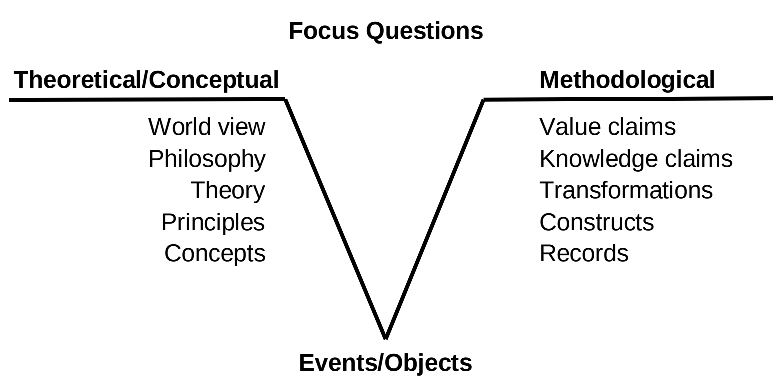
Conceptual Framework and Review of Relevant Literature

Conceptual Framework for the Study

Epistemological Relationships Among Conceptual Elements

This study examined teaching and learning with worked examples presented on the IWB. Gowin's Vee heuristic (Gowin, 1981) was used to guide understanding between the relationships of theory and practice concerning the two topics addressed. The Vee heuristic is a visual representation designed to show the relationships between the basic epistemological elements contained in both areas of research. Gowin's Vee (Figure 2.1) identifies 12 elements that contribute to the development of meaning and knowledge in the research (Novak, 1993).

Figure 2-1. Gowin's Vee Heuristic



Note: This figure illustrates the relationship between theory and practice of research.

The center of the Vee describes the research questions and includes any sub-questions that may be answered by the research. The lower part of the Vee depicts the events and objects to be studied to answer the research questions. The left side of the Vee articulates the conceptual component specifying the relevant concepts, principles, theories, and worldview influencing the study. The right side of the Vee is the methodological part of the research. It identifies the records and transformations that will be constructed and inferred to produce the value and knowledge claims of the study.

Gowin's Vee helps guide research by connecting theory and practice. The knowledge for the Vee for the proposed research was acquired through library research, Internet research, and coursework. The graphic representation of this knowledge (Figure 2-2) will provide a means by which to reflect and redirect the course of research when necessary.

Figure 2-2. Gowin's Vee - Connecting Theory and Practice

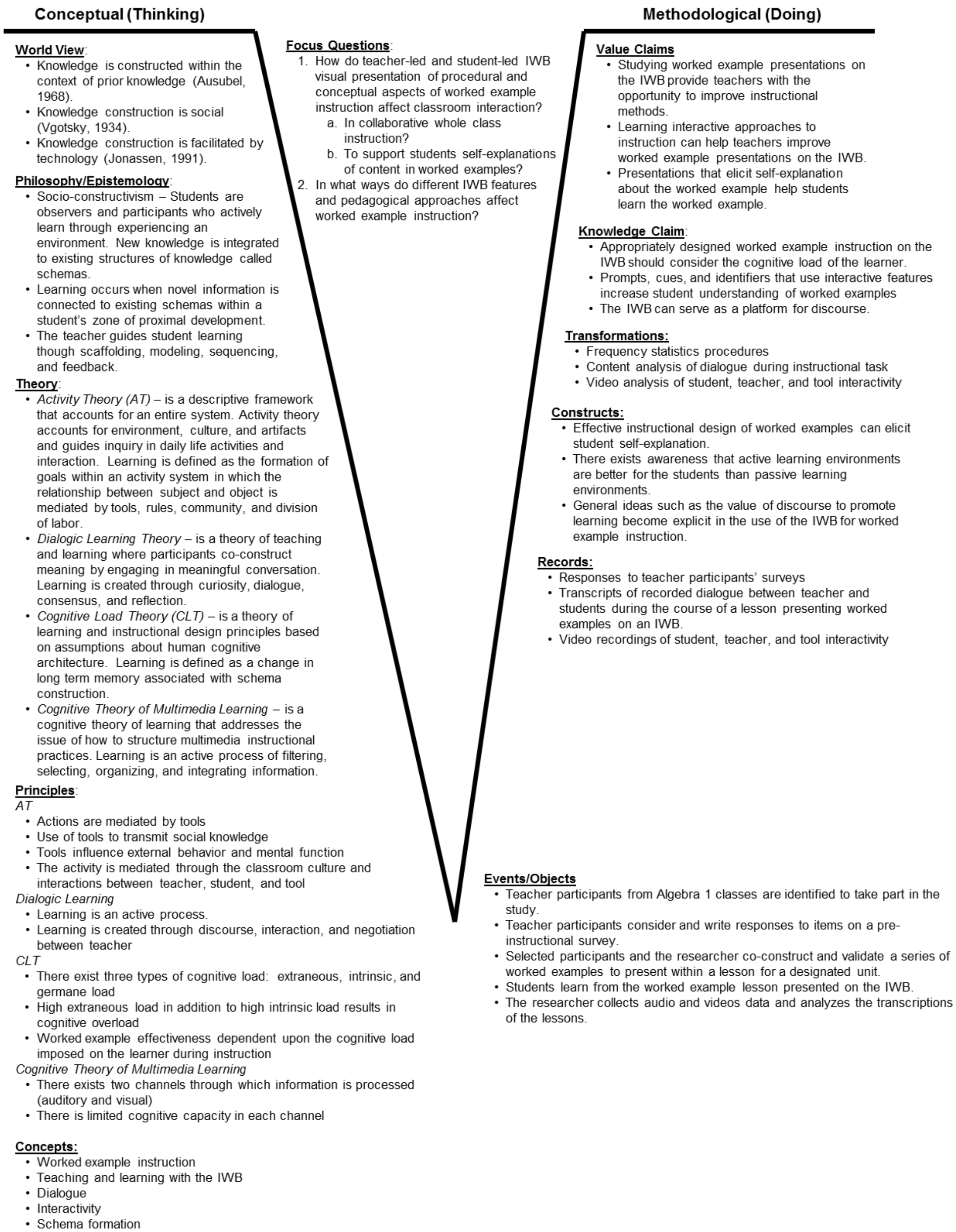


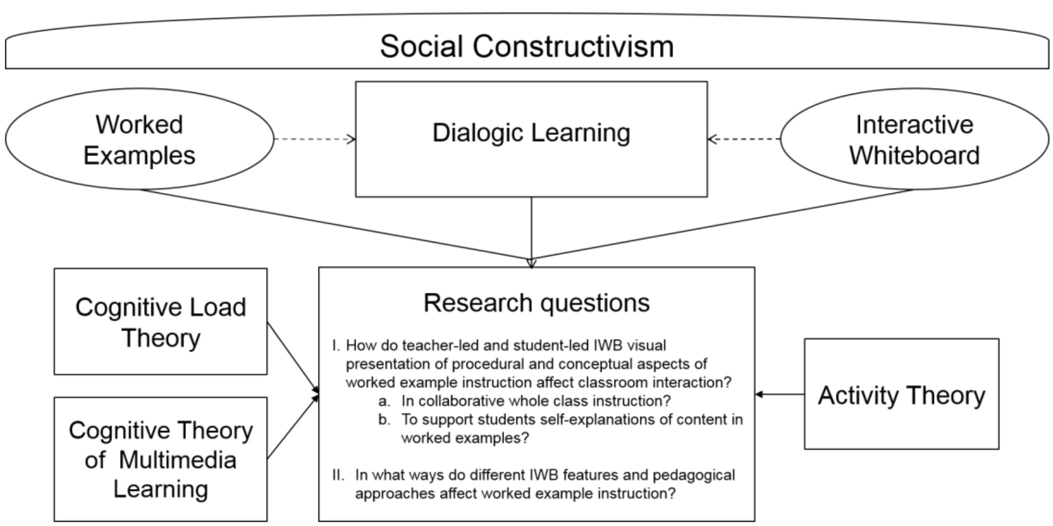
Figure 2-2. This figure illustrates the relationship between theory and practice of research for this study.

Theoretical Perspectives that Framed the Study

Socio-constructivism, Activity Theory, Dialogic Learning, Cognitive Load Theory and Multimedia Learning are the theoretical perspectives that framed this study (Figure 2-3). The following sections discuss each theoretical component as it relates to this study. The first section addresses socio-constructivism, the overarching theory of learning as applied to the research. The second section considers Activity Theory and the role of the IWB as a mediating tool for obtaining mathematical knowledge through interaction and dialogue. The discussion concludes with an analysis of the relevant theories of worked example instruction, cognitive load and effective multimedia presentations.

The conceptual framework diagram below in Figure 2-3 shows the relationship among the central theories elaborated as the conceptual framework for this investigation.

Figure 2-3. Conceptual Framework: Central Theories Related to Worked Example and IWB Areas of Research.



Socio-constructivism

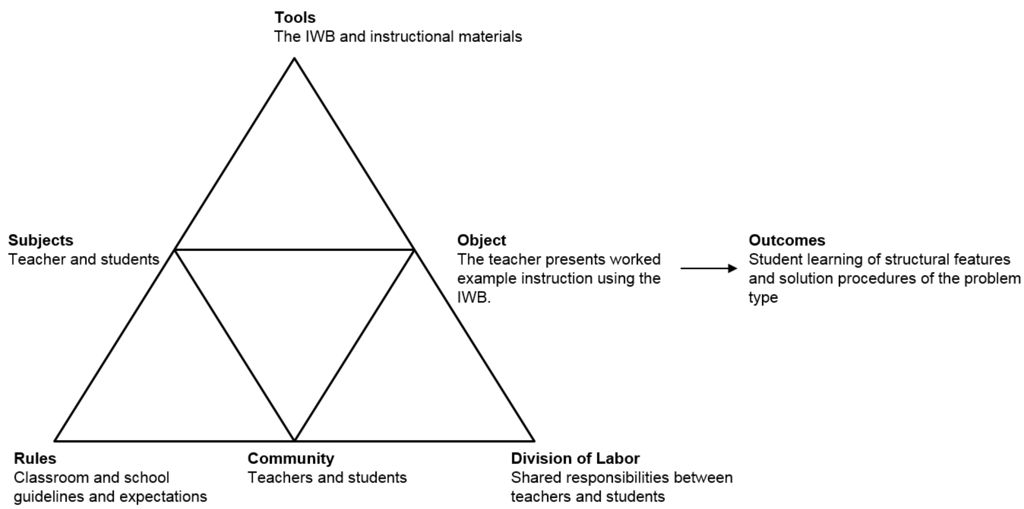
The rationale for this study derives from socio-constructivist theory. This theory is based on explicit assumptions about reality, knowledge, and learning. Social constructivism views the context in which learning occurs as central to learning itself. From this perspective, students are active participants in the construction of new knowledge through experiencing an environment (Vygotsky, 1978). Under the socio-constructive construct, knowledge is integrated into existing structures of knowledge. For the purpose of this study, pre-existing knowledge will be defined as ‘schemas.’ Sweller, Van Merrienboer, and Paas (1998) define schemas as “anything that has been learned and is treated as a single entity” (p. 256). They describe schemas as the elements of knowledge which in turn are used by the learner to create more complex schemas and thereby acquire new knowledge. As an extension of these principles learning occurs within a zone of proximal development (ZPD). ZPD is the difference between what a learner can do without help and what the learner can do with assistance from an expert guide (Vygotsky, 1978). Assistance is provided by the instructor whose roles are subject matter expert and mentor. The teacher contributes to the expansion of the ZPD and helps guide the student’s thinking through the instructional event. Thus, learning occurs when new knowledge is connected to existing schema within the student’s ZPD through the aide and guidance of the instructor.

This study examined how the IWB was used as a presentation tool to create conditions for learning about worked examples within the theoretical framework provided by socio-constructivism. The teacher guided students through a series of scaffolds *mediated* by a tool (the IWB) to facilitate schema construction about the conceptual ideas of the problem type.

Activity Theory

Activity theory (Engestrom, 2001) is used to explore the processes that occur when people engage in interactions that are mediated by cultural tools. Described by Nardi (1997), "Activity theory offers a set of perspectives on human activity and a set of concepts for describing that activity" (p. 8). Activity theory (AT) provides a framework to contextualize the use of the IWB as an instructional tool used for worked example presentations (See Figure 2-4).

Figure 2-4. Activity theory system for worked example presentations on the IWB



The basic unit of analysis in activity theory (AT) is the activity. An activity is defined as an action performed within a situated context. The action is directed towards an object that is considered the goal of the desired outcome. The desired outcome in this study was student learning from the worked example instruction. In the activity system, the teacher used the IWB as a technological tool in order to achieve the expected outcome. In essence, the IWB served as a mediating artifact facilitating interaction between the members of the community. The pedagogical methods used to present the worked example instruction guided the interactions between the students and teacher.

Dialogic learning

Both worked example research and IWB literature emphasize the importance of dialogue as a part of the learning process. This study focused on the relationship between classroom discourse and conceptual development of mathematics along with the reflective discourse generated by the student about the worked example. Specific issues addressed include both the teacher's role and the role of the IWB in supporting reflective shifts in discourse.

Worked example research recognizes self-explanation as an effective way to facilitate learning from worked examples. The literature implies that the design of the worked examples should encourage learners to reflect during the critical parts and goal operators of the solution procedure in order to understand the rationale behind the processes. Renkl (1997) investigated individual differences in learning from worked out examples with respect to the quality of self-explanations. Noting that characteristics of individual self-explanations were multidimensional, Renkl (1997) concluded that the learner's performance could be predicted by the qualitative difference of self-explanations. Based on the analysis, Renkl (1997) identified categories of learners who effectively self-explain as anticipative reasoners and principle-based explainers. Anticipative reasoners are those students who think of likely calculations to be performed in advance and compare their predictions with the next step in the worked out example.

Principle based explainers are those students who justify their calculations based on the mathematical principles that are applied in the worked out example.

Chi and VenLehn (1991) define self-explanation as a "comment about an example statement that contains domain-relevant information over and above what was stated in the example line itself" (p. 69). In their study, Chi, et al., (1989) analyzed explanations through the examination of the structure and the content of the student responses. The structure of the explanation depicts the purpose of the student explanation. Chi, et al., (1989) supposed that if a student understood an example solution then the conditions and consequences of each solution step would be clearly defined within the explanation. The data analysis of their study classified the structural discourse into four categories. Structural explanations were used to

- refine or expand existing conditions,
- explicate or infer consequences of an action,
- impose a goal or purpose of an action,
- give meaning to quantitative expressions.

To further examine the quality of self-explanation, Chi, et al., (1989) also included an analysis of the nature and content of the student responses. The analysis focused on the dialogue regarding principles pertaining to the topic along with other principle based knowledge about the subject matter. This study used similar categories to characterize the structure and content of student self-explanations about the worked examples presented on the IWB.

Cognitive Load Theory

The 'worked example effect' derives from research based on cognitive load theory. Cognitive load theory provides a model of human cognitive architecture and assumes that working memory is very limited in terms of being able to store and process information. The human cognitive architecture consists of a working memory that has a limited capacity of seven elements, or chunks, of information when holding information (Miller, 1956). Remembering the digits of a phone number until you write them down is an example of holding information in the working memory. Processing information is the changing of information and has significantly less capacity within the working memory.

Another assumption of cognitive load theory is that long-term memory can store large amounts of information through an organizational strategy termed schemas. Unlike working memory, long-term memory has potentially unlimited capacity and holds information in schemas. Schemas are domain-specific knowledge structures within long-term memory. They help learners determine problem states and the associated moves needed to obtain the solution (Kalyuga, Chandler, Tuovinen, & Sweller, 2001). Cognitive load theory views the formation of schemas as the process of learning and knowledge acquisition. Understanding occurs when learners employ cognitive processes and relate new information to an existing schema. "According to schema theory, it is through the building of increasing numbers of ever more complex schemas by combining elements consisting of lower level schemas into higher level schemas that skilled performance develops" (Sweller, et al., 1998, p. 256). Additional learning takes place when the schemas modify processing efforts from controlled to automatic. Once a schema is acquired and becomes automated, the processing load of that schema within the working memory is reduced. As a result, processes and procedures can be handled in working memory with very little conscious effort regardless the complexity of the acquired schema (Sweller, et al., 1998).

Learning is an active, constructive process where the learner uses available cognitive resources to create new knowledge from the instruction and previously stored schemas. Cooper and Sweller (1987) defined schema as a construct that allows problem solvers to group problems into categories in which the problems in each category require similar solutions. They indicated that worked examples support schema acquisition of domain content. Sweller and Cooper (1985) asserted that worked examples will increase the strength and number of schemas acquired. They concurred that the use of worked examples can direct attention to the problem states and the components of an expert solution.

The knowledge required to solve mathematics problems may contain a number of different problem states or schemas. A conceptual understanding of multiplication and the patterns that lie within can be said to form a schema used to solve a variety of problems. Some students use this schema to solve problems with very little working memory load. Subsequently, the students are able to apply the learned schema to new types of problems that use multiplication. Students who lack a conceptual understanding of multiplication often struggle with solving novel problems due to the heavy load imposed on the working memory by the solution procedures. Consistent with cognitive load theory, the student uses more working memory to hold and process information about multiplying and is unable to solve the given problem in an efficient and effective manner.

Cognitive load theory addresses human cognitive architecture related to the concepts of short-term and long-term memory, as well as schema acquisition and automation (Sweller, et al., 1998). The theory also addresses information structure by classifying three categories of load imposed on a learner during an instructional event: extraneous, intrinsic, and germane load. The three categories of load will be discussed briefly here and then examined further during the discussion of the worked example literature.

Extraneous load is the cognitive processes generated by irrelevant mental activities experienced by the learner during instruction. Extraneous load is caused by the instructional design and presentation of information. Chandler and Sweller (1991) note that poorly designed instructional formats can "result in students engaging in cognitive activities far removed from the ostensible goals of the task" (p. 294). To avoid extraneous load, they suggest "that information should be presented in ways that do not impose a heavy extraneous cognitive load (Chandler and Sweller, 1991, p. 295). Instructional efficiency depends on the extraneous load imposed on the learner by the instructional design and presentation format. In order to facilitate schema formation, instructional strategies, such as worked examples, should be designed to decrease ineffective load bearing requirements.

In addition to extraneous load, working memory may be affected by intrinsic load. Intrinsic load is the inherent level of difficulty or complexity associated with the instructional activity. Intrinsic load is measured by the amount of interactivity between the elements in the content material. Sweller and Chandler (1994) defined element interactivity as instructional content involving of a range of components or elements. It is proposed that the cognitive load associated with material to be learned is strongly related to the extent to which the elements of that material interact with each other. These elements are said to interact if there exists a relationship between them. Therefore, the working memory load is dependent upon the number of elements in the material that must be processed simultaneously.

Instruction that contains low element interactivity results in a low intrinsic load. Whereas, instruction that contains high element interactivity brings about an increased level of intrinsic load within the working memory. Originally, the level of intrinsic load was thought to be unalterable by the instructional design of the presentation given the inherent nature of the material (Sweller and Chandler, 1994). However, it was later found that intrinsic load could be influenced by dividing instruction into smaller pieces, thus decreasing the level of interactivity between elements.

First described by Sweller, et al., (1998), germane load is the load that frees working memory capacity thereby facilitating schema formation. Germane load can be influenced by instructional design. The design of worked example presentation should optimize germane load in order to help domain specific schema constructions. This is unlike extrinsic and intrinsic loads where the goal of the presentation design is to diminish the effects of both types of load on the learner. Under the cognitive model, the amount of germane load is a determinant of instructional efficiency. Effective instructional design reduces the extraneous load and transfers the surplus of working memory available to germane load.

Cognitive Load Theory was used to guide the design of the worked example instruction. Specifically, CLT was used to identify possible load bearing effects of the IWB worked example presentation. The design of the worked example presentation considered cognitive load experienced by learners during the lesson as a whole and within the single worked example presented on the IWB.

Mayer's theory of multimedia learning

Mayer (2001) defines multimedia as the presentation of material in the form of pictures and words. Pictures can include photographs, screen shots, and other visual forms. Words can be expressed using text on a page or computer screen, in spoken form, and other verbal manners. Mayer and Moreno (2003) developed the cognitive theory of multimedia learning by integrating cognitive load theory (Chandler and Sweller, 1991), dual-coding theory (Pavio, 1986), and Baddeley's (1986) working memory model. Mayer's theory of multimedia learning offers principles to help guide the design of multimedia instruction.

Mayer's theory of multimedia learning is based on three assumptions. First, there exist two separate channels (auditory and visual) for processing information. The theory of multimedia learning suggests people learn better from words and pictures than from words alone, and learning is deeper when appropriate pictures are added to text. The second assumption states the human mind is limited in its capacity to effectively process new information within the working memory. "In accordance with the limited-capacity assumption, working memory is limited in the amount of knowledge it can process at one time – so that only a few images can be held in the visual channel of working memory, and only a few sounds can be held in the auditory channel of working memory" (Mayer, 2001, p. 66). Finally, multimedia learning theory assumes that learning is an active process by which the learner integrates new information into existing schemas (Chandler & Sweller, 1991). Learners actively filter, select, organize, and integrate information during the learning process.

Mayer's theory of multimedia learning provides a theoretical rationale upon which nine principles of multimedia were developed. The nine principles provide a framework for designing instruction that benefit learning outcomes by considering ways that are consistent with how the human mind works.

Mayer's nine principles for the design of multimedia instruction and their definitions are:

- *Multimedia principle*: People learn better from words and pictures than from words alone;
- *Segmenting principle*: People learn better when a multimedia lesson is presented in learner-paced segments rather than as a continuous unit;
- *Pre-training principle*: People learn better from a multimedia lesson when they know the names and characteristics of the main concepts;
- *Modality principle*: People learn better from animation and narration than from animation and on-screen text;
- *Coherence principle*: People learn better when extraneous words, pictures, and sounds are excluded rather than included;
- *Redundancy principle*: People learn better from animation and narration than from animation, narration, and on-screen text;

- *Signaling principle*: People learn better when the words include cues about the organization of the presentation;
- *Spatial contiguity principle*: People learn better when corresponding words and pictures are presented near rather than far from each other on the page or screen;
- *Temporal contiguity principle*: People learn better when corresponding words and pictures are presented simultaneously rather than successively;

To support effective instructional design, the principles contextualized through Mayer's theory of multimedia learning influenced the design of the worked example instruction on the IWB for this research. Specifically, the worked example presentations designed for this research included text, diagrams, and manipulatives. Mayer's principles were used to identify effective design strategies to support student learning of worked examples when using the IWB.

Review of Relevant Literature

The literature review consists of selected research concerning worked examples and interactive pedagogy with the IWB as these two conceptual elements provided a construct in which to situate the research. The first section of this review contains resources related to worked example instruction and its effect on student learning. Worked example instruction will be defined and described through the theoretical construct of cognitive load. Then, an analysis of a worked example literature review written by Atkinson, et al., (2000) is presented and specific factors moderating the effectiveness of worked example presentations are identified. The review pinpoints instructional design principles that describe effective example design and solution procedure presentation. Further, Atkinson et al., (2000) propose organizational guidelines for the presentation of worked examples at the lesson level. The results are discussed in terms of the theoretical and practical implications for learning from worked example instruction.

The second section analyzes sources related to the use of the IWB as a catalyst for student learning. This part describes how the features and manipulations of the IWB are used during an instructional event to foster learning and explicate pedagogical strategies which can cultivate student learning. The analysis of the research identified the ways in which the IWB can direct learner attention and support interactive pedagogy. Additionally, the research exploited the potential of the IWB as a mediating artifact that provides a space for shared understanding between the teacher and student establishing a link between dialogic learning and the IWB.

The 'worked-example effect' (Sweller & Cooper, 1985) stems from research conducted on cognitive load. The cognitive load theory provides a model of human cognitive architecture and assumes that working memory is very limited in terms of being able to store and process information. Another assumption of cognitive load theory is that long-term memory can store massive amounts of information known as schemas. A schema is essentially a mental framework for understanding and remembering information. Schemas categorize elements of information according to how they will be used (Chi, Glaser, & Rees, 1981). When new schemas are formed or existing schemas altered, learning occurs.

Given the extensive research on worked examples, there is a broad array of terms used throughout the review (Table 2-1). If necessary, please consult Table 2-1 for the descriptions of common terms used in worked example research.

Table 2.1

Literature Review Terminology

Term	Description
Completion (faded) problems	Completion problems present worked examples in a sequence that isolates concepts and procedures of the problem. The examples gradually progress a learner through the series of procedures required to obtain the solution.
Interactivity	Interactivity defines the interaction between student, teacher, and tool and includes technical, physical, and conceptual components.
Structure features	Structural features are the fundamental mathematical procedures needed to solve the problem. They form the conceptual knowledge that is the basis for schema construction.
Sub-goals	Sub-goals organize solution procedures into chunks of meaningful information. As an instructional device, sub-goals link the subsets of conceptual aspects to a solution procedure. To distinguish what constitutes a sub-goal depends on the domain in which it resides and the instructor's view of the important concepts of the domain knowledge.
Surface features	Surface features are the specific story lines in a problem. They are used to establish a context for the learner. Typical worked examples in the algebra domain offer real world situations such as the degrees on a thermometer or the yards gained or lost on a football field to illustrate the concept of integers.
Variability	There are two types of variability discussed in worked example research. First, structural variability refers to different problem types and conceptual ideas within worked examples. Second, surface feature variability refers to the variance of story lines in a series of worked examples

Three types of cognitive load

The three types of cognitive load, extraneous, intrinsic, and germane, were introduced previously in this chapter. The following discussion examines the types of cognitive load and how they relate to the effective design of worked examples.

Extraneous cognitive load can be caused by the design of the instruction. In a series of six experiments, Chandler and Sweller (1991) found that high levels of extraneous load influences the degree to which learning can be facilitated. The cognitive load generated by irrelevant activities can impede acquisition of concept. Therefore, instruction should be designed so as to reduce the extraneous load. The research defines three effects known to cause extraneous load in the presentation of worked examples: Split-attention, redundancy, and expertise-reversal.

The split attention effect occurs when students are required to integrate two or more sources of information while learning from instructional materials. As a result of the split format, the student experiences an increase in extraneous cognitive load. Tarmizi and Sweller (1988) found that when learners were required to split attention among multiple sources of information learning efficiency decreased. They called the result “the split attention effect” and concluded that schema acquisition was hindered due to the extraneous load imposed by the separate material. Tarmizi and Sweller (1988) recommended designing worked examples so the presentation reduces the need for students to integrate multiple sources such as text and diagrams. In turn, this will lessen extraneous cognitive load imposed on the learner.

The split-attention effect is not limited to mathematics. In any discipline, when the instructional design imposes a high visual cognitive load, the result is an increase in extraneous load on the learner. Chandler and Sweller (1991) used biology materials in the form of diagrams and instructions explaining the flow of blood around the heart, lungs, and body. The first group received a single self-explanatory diagram of the heart, lungs, and body. A second group was given instructions with textual information presented separately from a diagram of the heart, lungs, and body. This group had to assimilate the textual information with the related diagram. The third group used a modified integrated diagram where the instructions were placed directly on the diagram. The learners in the diagram-only group found it easier to integrate and process both forms of visual information and, as a result, performed better on the post-test than the other two groups. Accordingly, learners were able to devote more cognitive attention and mental resources to processing the self-explanatory diagram and perform better on the post-test. The cognitive load generated by the disparate pieces of information impeded knowledge acquisition. Therefore, instruction should be designed to integrate text into diagram wherever possible in order to avoid the split-attention effect.

Another source of extraneous cognitive load caused by poor instructional design is the redundancy effect. Chandler and Sweller (1991) found that the redundancy effect occurs when multiple of sources of information are autonomous and can be understood in isolation. In an experiment using biology instructional materials, the modified integrated diagram included redundant information placed on top of the diagram of the blood flow through the heart, lungs, and body. The results of the study showed that the presence of ostensibly useful but unnecessary instructional explanations were detrimental to the learning outcomes. Once the students understood the material, redundant information pertaining to the lesson increased extraneous cognitive load and thus hindered learning.

Similar to redundancy, the expertise reversal effect imposes extraneous cognitive load. When a learner becomes more experienced in a domain, the advantage of instructional guidance decreases (Kalyuga, Ayres, Chandler, & Sweller, 2003). Kalyuga et al., (2003) suggested that under some conditions, when fully guided instructional material is presented to more experienced learners, a part or all of the instructional guidance might be redundant and impose unnecessary load on limited working memory resources. In contrast, that same material may be essential for less experienced learners (Kalyuga et al., 2003). Therefore, for worked examples to be effective, it is important to consider the level of experience of intended learners.

In addition to extraneous load, working memory may be affected by intrinsic load. Intrinsic load is the inherent level of difficulty or complexity associated with the instructional activity. Intrinsic load is measured by the amount of interactivity between the elements in the content material. Sweller and Chandler (1994) defined element interactivity as instructional content involving a range of components or elements. These elements are said to interact if there exists a relationship between them. Therefore, the working memory load is dependent upon the number of elements in the material that must be processed simultaneously.

Instruction that contains low element interactivity results in a low intrinsic load. Whereas, instruction that contains high element interactivity brings about an increased level of intrinsic load within the working memory. Originally, the level of intrinsic load was thought to be unalterable by the instructional design of the presentation given the inherent nature of the material (Sweller and Chandler, 1994). However, it was later found that intrinsic load could be influenced by dividing instruction into smaller pieces, thus decreasing the level of interactivity between elements. Clark, Nguyen, & Sweller (2006) defined the smaller pieces as "subschemas" (p. 12).

Gerjets, Scheiter, and Catrambone (2004) utilized the concept of subschemas in their research the on molar and modular worked examples. Molar worked examples focus on problem categories and their associated solution procedures. Modular worked examples break down complex solutions into small meaningful solution elements. They found that by using a modular worked example format, task-related intrinsic load was reduced due to the decrease of interactivity between the elements of the problem solving process.

First described by Sweller, et al., (1998), germane load is the load that frees working memory capacity thereby facilitating schema formation. Germane load can be influenced by instructional design. The design of worked example presentation should optimize germane load in order to help domain specific schema constructions. This is unlike extrinsic and intrinsic loads where the goal of the presentation design is to diminish the effects of both types of load on the learner. Variability and eliciting self-explanation are both strategies that can be used to increase germane load through instructional design.

The research indicates that variability over problem situations is a strategy that can be used to increase germane load. Paas and Van Merrienboer (1994) compared low and high variability conditions in conventional problems and worked examples. The purpose of the study was to relate the effects of variability to training performance, transfer performance, and cognitive load. The results showed that students who studied worked examples gained most from the high variability examples than the students who used the conventional method. However, Paas and Van Merrienboer (1994) noted that in order to benefit from high variability conditions, the instructional design must minimize extraneous cognitive load. Quilici and Mayer (1996) demonstrated that high variability of structural features within the worked examples facilitated schema construction and, hence, increased germane load. By redirecting attention from extraneous load to germane processes, variability within the instructional design can facilitate schema formation.

Research also endorses self-explanation as an effective way to increase germane load and facilitate learning from worked examples. Renkl (1997) describes the characteristics of effective self-explanation as being able to describe the principles and goal operators of a solution procedure. Therefore, the design of the worked examples should encourage learners to reflect during these critical parts in order to understand the rationale behind the procedures used to obtain the solution. From this conclusion, the question that arises is how can the design of the worked example presentation induce self-explanation? The answer depends upon whether the self-explanation is used to understand the principles behind the content (the why of the solution procedure) or the goal operator combinations needed to obtain the solution (the how of the solution procedure).

Renkl, Atkinson, and Grobe (2004) ascertained that faded examples triggered student self-explanation. Faded examples provide a link between a worked example and conventional problem solving. From a cognitive load perspective, the faded approach frees working memory capacity by isolating individual steps, thereby reducing the load imposed on the learner. Renkl, et al., (2004) concluded the faded step condition fostered self-explanation as the learners decided what goal operator was needed to obtain the next step. They further purported faded examples are most effective when using backwards fading design. This entails presenting the last solution step of the first practice problem, the last two solution steps of the second practice problem, and so on, until the student is left to solve a problem independently. Schwonke et al., (2007) found evidence that the faded procedure leads to deeper conceptual understanding through explanation thus fostering schema construction. Their study concluded that when learning from faded worked examples it is valuable to direct attention to the goal operating combinations needed to solve a problem. By directing attention to the goal operating combinations the sub-goals become more salient.

Another method to induce self-explanations is to design prompts to engage the learner in a self-explanation activity. Schworm and Renkl (2002) investigated to what extent learning from worked examples could be fostered by self-explanation prompts and by providing instructional explanations. The results showed that prompting self-explanations had favorable effects on learning outcomes. Their study also found that instructional explanations only partially enhanced learning and at times they were detrimental to knowledge construction as a result of the redundancy effect. Gerjets, et al., (2006) also examined whether learning was enhanced by self-explanation prompts and worked examples in modular format. It was determined that either the instructional explanations or the self-explanation prompts were not effective for learning since the design of the modular examples provided the learner sufficient instructional support to incite self-explanations. Hence, the self-explanation prompts forced learners to process redundant information and impeded knowledge construction.

Cognitive load theory is concerned with instructional techniques for managing working memory load in order to facilitate the changes in long term memory associated with schema construction and automation. Instructional strategies, such as worked examples, should decrease ineffective load bearing requirements, minimize the number of unrelated interacting elements, and optimize germane load to facilitate domain specific schema constructions. Further, when designing worked example instruction, it is important to analyze the internal structure of problem design to determine whether or not to elicit self-explanations. When sufficient support is provided to the learner by instructional techniques, such as modular examples, prompting for self-explanation may impose a heavier working memory load due to the redundant information that learners must process. To assess whether or not to include self-explanation strategies in a modular presentation format, the learner's prior knowledge should be considered.

The research provides a number of suggestions to guide the design of effective worked example presentations. Worked example research establishes that instructional efficiency depends on the cognitive load imposed on the learner by the content and the instructional design. Under the cognitive model, an effective example reduces extraneous load and transfers the surplus of working memory to germane load to facilitate schema constructions. This implies the presentation of the worked examples should avoid extraneous load bearing effects such as split-attention and redundancy.

Additionally, the design of the worked example presentation must address the intrinsic load imposed on the learner by the material. The level of interactivity between the elements of the material in conjunction with learner prior knowledge determines the amount of intrinsic load experienced by the learner. Interactivity is only effective when it is carefully designed to trigger the processing of central aspects to the worked example. Dividing complex solutions into smaller meaningful chunks can decrease interactivity between elements and is an effective way to manage the intrinsic load of the material. In the case of a high interactivity lesson, using a modular design will help decrease the interactivity between the content elements. Then again, if there is low interactivity between the elements of the material, teachers should consider how much instructional support is needed in order to avoid redundancy and creating extraneous load.

The amount of germane load is a determinant of worked example instruction effectiveness. Increasing germane involves redirecting learner attention to the problem state and structural features of the worked example that are relevant to learning. Presenting multiple examples of the same problem type is an effective way to focus learner attention on the structural features of the problem thereby increasing germane load. Variability over problem situation can also direct learner attention to the structural features. When a new problem is presented students search their memory for a similar problem. By emphasizing structural features rather than surface stories students are more apt to choose the appropriate solution procedure.

Presentations that generate questions resulting in student self-explanation about the worked example are another effective strategy to increase germane load. The quality of self-explanation is a major factor in determining whether learners benefit from studying examples. Inclusion of gaps or prompts should be positioned strategically to encourage productive learner self-explanation of the worked examples. When utilizing completion problems, the instruction should direct learner attention to the procedures and rationale used to find and understand the problem solution. This entails constructing the worked example based on the structural features of the problem type and the processes used to obtain the solution.

Principles of effective worked example instruction

Atkinson, et al., (2000) conducted a literature review on worked examples research that focused on the effective presentation and use of worked examples during instruction. In the review Atkinson et al., (2000) identified factors that influence learning from worked examples. Then, based on the design principles revealed from the literature, they presented an instructional model applicable to the use of worked examples in a real classroom setting.

According to Atkinson, et al., (2000), worked example instruction should include intra-example elements of the presentation and inter-example features of the problem types in order to regulate worked example effectiveness. The intra-example principles provide insight on how to integrate the different elements, such as text, diagram, and aural information, when presenting worked examples. Principles of inter-example consider the sequence and arrangement of worked examples during the instructional presentation. Table 2-2 summarizes the intra-example principles as suggested by Atkinson, et al., (2000).

Table 2-2

Intra-examples Atkinson Integration Model of Intra-Examples

Integration	Problem	Recommendation
Integrating Text and Diagram	Tarmizi and Sweller (1988) and Ward and Sweller (1990) found that splitting attention among multiple sources of information imposed a heavy cognitive load on the learners.	Worked example presentations should integrate text into the diagram wherever possible in order to avoid the split attention effect.

Table 2-2 *(continued)*

Integration	Problem	Recommendation
Integrating Aural and Visual Information	Mousavi, Low, and Sweller (1995) found that mixed mode formats (visual-auditory and simultaneous) facilitate learning more than the conventional single mode format (visual-visual)	Examples should be constructed to maximally integrate all sources of information (text, diagrams, and aural) into one unified presentation except when an example display is complex.
	Under "high visual" conditions Jeun, Chandler, and Sweller (1997) found that a mixed mode format imposed a heavy cognitive load on the learners. Students will use a large amount of cognitive effort trying to locate the elements of the example to which the aural presentation is referring, thus increasing cognitive load.	When presenting a complex diagram, explicit direction or cues to the relevant parts of the example must accompany the aural explanation.
Integrating Steps and Subgoals	Catrambone and Holyoak (1990) examined structuring examples to emphasize sub-goals. They found that students who used cues, such as highlighting, outperformed the students in the non-highlighting group.	Distinguish the sub-goals of the problem by labeling each step or visually isolating steps in the example presentation.
	Renkl, et al., (2004) examined whether the position of the fades steps influenced learning outcomes. They concluded that students learned most about those principles that were faded. Further they asserted the backward fading approach was the most effective use of the faded example strategy.	When designing instruction one must determine what steps are best supported by the fading procedure and sequence the faded steps using the backward approach.

Atkinson et al., (2000) identified three factors that moderate effective worked example instruction. First, they determined that it is important to consider how the example is designed, particularly the way in which the solution is presented. The earlier research studies reviewed by Atkinson et al., (2000) examined the integration of text and diagram within the worked example presentation. The literature concurred that the effective design of worked examples must avoid the split attention principle. In addition to the integration of visual elements, the aural and visual presentation of material was found to support problem solving performance as well. The preferable presentation technique is through dual code modality whereby students use two processing channels while learning from worked examples

The more recent empirical studies reviewed by Atkinson et al., (2000) focused on the integration of steps and sub-goals. Sub-goals structure examples into conceptually meaningful chunks of a problem's solution and have been found to have a positive impact on learning. Based on their review, highlighting sub-goals increased the likelihood that learners will be able to transfer the problem's structure to novel problems. Labeling or visually isolating a sub-goal directs the learner's attention to the structural nature of the problem, and thus facilitates schema acquisition. Further, the design of the sub-goal method provides structural cues that encourage learners to determine the function of the sub-goals which in turn promotes self-explanation.

Principles of inter-example consider the sequence and arrangement of worked examples during the instructional presentation. Table 2-3 examines the inter-example principles as suggested by Atkinson, et al., (2000).

Table 2-3 Atkinson Model of Inter-Examples Features within lesson design

Worked example feature	Problem	Recommendation
Multiple Examples	Reed and Bolstad (1991) found that students provided with both simple and complex examples outperformed students who were provided with a single example only.	Understanding of problem type is enhanced when at least two examples are presented for each type of problem taught.
Varying Problem Types	Paas and Merrienboer (1994) examined the variability of problems within a lesson. They found that students in the worked example condition benefited more from lesson variability than students in the conventional condition	Variability of problem types within a lesson produces learning benefits, but only in combination with instruction designed to minimize cognitive load.
Variability in Surface Stories	Quilici and Mayer (1996) found that the students presented with instructional activities that targeted structural features were better able to categorize statistic problems. However, they also noted that providing a brief exposure to structure emphasizing examples without supporting guidance decreases the likelihood of positive learning results.	When a new problem is presented, students search their memory for a similar problem. By emphasizing structural similarities, students are more likely to choose the appropriate solution procedure

Table 2-3 (Continued)

Worked example feature	Problem	Recommendation
Example-Problem Pairs	Trafton and Reiser (1993) examined the pairing of examples and practice using a LISP programming curriculum. They concluded that presenting examples immediately followed by practice produced better learning outcomes than lessons in which a blocked series of examples was by a blocked series of practice problems.	Examples must be available in memory during problem solving, therefore, pair each worked example with a practice problem immediately following.

In addition to addressing issues regarding the design of worked examples, Atkinson et al., (2000) suggested that on a macro-level it is important to consider how worked examples are sequenced and arranged during instruction. From the research reviewed, Atkinson et al., (2000) suggested the following design considerations when sequencing and arranging worked examples within a lesson. First, research on multiple examples supported that learning is enhanced when at least two examples are presented for each type of problem taught. Additionally, the findings confirmed that varying problem sub-types within an instructional sequence are beneficial, but only if the design minimizes cognitive load. Furthermore, Atkinson et al., (2000) found that interspersing problem-practice pairs within a lesson enhances learning more than a blocked series of examples followed by a blocked series of practice problems.

After addressing effective factors of example and lesson design, Atkinson et al., (2000) examined the ways in which examples are used by the learner within the practice of self-explanation. The literature concluded that self-explanation is an important learning activity when using worked examples but noted most learners self-explain in a passive manner, and in doing so, fail to acquire the benefits afforded by the self-explanation activity. Therefore, the instructional design of the worked example presentation should include prompts and cues to elicit student self-explanation of the structural features and procedures of the solution.

From the review, Atkinson et al., (2000) determined three design strategies used to induce self-explanation. These considerations include structural manipulation, direct training, and the use of social incentives. The research concluded that using structural manipulations and direct training fostered self-explanations; the use of social incentives to induce self-explanation proved to be less a favorable strategy.

Future worked example research possibilities include studying the impact of technology on the presentation of worked example instruction. Visual presentation is an important component of mathematics instruction. Using colors to differentiate the various sub-goals necessary to solve multi-step problems could give students visual cues to help them remember problem solving techniques. Also, interactive movement across the screen can be used as a form of visual representation. The interaction allows students to be more actively engaged and visualize the mathematical procedures needed to obtain the solution. Using innovative technology can provide exciting and engaging opportunities for worked example instruction. The next section expands on the use of technology when presenting worked examples by discussing pedagogy as it relates to the interactive whiteboard.

Interactive Whiteboard

The interactive whiteboard (IWB) allows the presentation and manipulation of images, text, and video on a large touch-sensitive screen. The IWB connects to a projector that projects the content it takes from the computer onto the screen. Special software is installed on the whiteboard and offers a variety of features that can be used for instruction. It is also possible to add new images and animations from the web or other programs to existing ones in the software. Teachers can use ready-made materials or make their own materials and resources to support content delivery in lessons. In addition, the teachers can save the work and return to the saved files at any time.

Current research suggests that using the IWB as an instructional tool is an effective way for teachers and students to interact with and engage in multimedia learning. Current literature considers the affordances of the IWB as a mediating artifact that facilitates an interactive learning environment. Gillean, et al., (2007) describes the IWB as a mediating artifact in interactions between teacher and students and students' interactions with one another. Further implications of this theoretical framework enable researchers to better assess the impact of the IWB on teaching and learning and apply the results to the design of effective instruction.

The Education Resources Information Center (ERIC) and the University of Kentucky (UK) Library databases were used to search for articles related to the IWB and pedagogical practice. Search terms included the key words - interactive whiteboard, strategies, instructional supports, effective pedagogy, and dialogic interactivity. The search criteria were further refined by considering only original peer reviewed research and conceptual articles. This review concurs with prior literature reviews in that most research is conducted as small case studies utilizing interviews, surveys, and questionnaires.

The analysis of literature resulted in the identification of common themes similar to the prior reviews. The literature describes how the features and manipulations of the IWB are used during an instructional event and identifies the effective pedagogical characteristics that contribute to quality instruction. Additionally, the research establishes links between the IWB as a mediating artifact and dialogic learning. The following discusses the results of the literature analysis.

IWB function and use in the classroom

The IWB is an instructional tool that allows computer images to be displayed on a board using a digital projector. A teacher or student can manipulate elements on the board by touching the figure directly on the screen. Items can be dragged, clicked, and copied. Notes can be handwritten and then transformed into text and saved.

The IWB software provides a variety of functions on the display in the classroom (Glover, et al., 2005) such as:

- Drag-and-drop (objects on board can be moved around)
- Hide-and-reveal (objects placed over others can be removed)
- Highlighting (transparent color can be placed over writing or other objects)
- Animation (objects can be rotated, enlarged, and set to move along a specified path)
- Indefinite storage and quick retrieval of material
- Feedback (when a particular object is touched, a visual or aural response is generated)

In addition to these manipulations, the teacher can also write on the IWB. This could involve using the IWB in a similar way to writing on a normal whiteboard but could also include writing over other objects to illustrate particular points or annotating previously covered content. Miller, Glover and Averis (2004) conducted a study on secondary mathematics classes and the use of the IWB for instructional support. They found that the use of color when writing over objects can be used systematically in order to direct learner attention (Miller et al., 2004). Glover, et al., (2007) found the affordances of the IWB features can be used to direct learner attention by employing visual support and, in turn, prompt discussion regarding the content. Jewitt, Moss, and Cardini (2007) also demonstrated that using the features and manipulations of the IWB can direct learner attention. In their study, learner attention was directed by using color, images, and sound. Jewitt et al., (2007) hypothesized the design of IWB texts can better direct learner attention and found the features of the IWB provided a multiple ways to direct the attention of the student. However, Jewitt et al., (2007) pointed out sequence and timing of emphasis is an important consideration for effective design.

Besides directing learner attention, the analysis of the research revealed that the affordances of the IWB can contribute to learning by employing multiple representations of concept through visual, aural, and kinesthetic modalities. Gillen, et al., (2007) examined the use of the IWB in primary classrooms. In the lesson, the children used the block-reveal feature. The children revealed the blocks by touching the screen and then placed them in order to obtain the correct recipe. The authors concluded the kinesthetic approach deepened understanding of the concept (Gillen et al., 2007). In a study by Jewitt et al., (2007) the lesson focused on polygon external and internal angles. The teacher used Geometer's Sketchpad, a software package that has been specifically designed for teaching mathematics in conjunction with the IWB. The IWB presentation included flipcharts, hyperlinks, diagrams, graphs, and tables. During the lesson the teacher used visual and dynamic supports to reinforce the content objectives. This resulted in a multi-modal and multi-sensory lesson that engaged students. In a study by Hennessey, Deaney, Ruthven, and Winterbottom (2007), the teacher used the IWB to display key concepts and encouraged verbal interpretations of a representational display by the students. The teacher annotated the diagram as instructed to do by the students. Next, the teacher applied animation to the diagram producing a dynamic representation of the student-created material. This resulted in a mental image of the dynamic process presented (Hennessey et. al., 2007).

Moss et al., (2007) discussed the potential of the technology and identified positive features of IWBs in teaching and learning. Through student interviews and observational data, the analysis showed the use of color, animation, and dynamic applications were the features of the IWB that students reported as most helpful in facilitating learning. (Moss et al., 2007). Moss et al., (2007) found the multi-modal affordances of the IWB supported a wide range of different learning styles and enabled teachers to model concepts in a variety of ways in order to deepen student understanding.

The literature suggests a number of effective strategies when utilizing the features of the IWB. Beauchamp and Kennewell's (2008) study outlines a list of distinct actions that can be carried out when using the IWB for multi-modal instruction. Beauchamp and Kennewell (2008) noted the affordances of the IWB can be used to represent relationships between variables in multiple ways. The IWB features facilitates learning through a visual, aural, and textual combination and the IWB also can be used to represent the dynamic content of processes in motion. Miller, et al., (2004) found similar results and concluded the use of the IWB features supports multiple representations through various modalities. The research implies that the IWB is a very powerful tool for the presentation of content utilizing multiple representations and multi-modal instructional strategies.

Overwhelmingly, the literature concurs that the effective use of the features of the IWB directly relate to the proficiency in which the teacher uses the tool for instructional presentation. The next section will discuss the impact the IWB has on pedagogical development.

Pedagogical approaches and the IWB

An important trend in the early research is the change from detailing the uses and functions of the IWB to understanding of the development of effective pedagogy. Miller et al., (2004) described how this process reflects the process of technological change in general. Additionally, Miller et al., (2004) explained that as teachers become more proficient in the use of the IWB they begin to recognize a pedagogical change from teacher-centered to interactive. As a result of this realization, the IWB becomes a potential catalyst for further change in effective teaching and learning.

The review by Higgins, et al., (2007) served as an update to the previous reviews. They sought to identify the changes in classroom learning as it relates to the IWB and multi-modal teaching and learning. Further, the authors elaborated on the relationship between the IWB and dialogic learning. Higgins et al., (2007) detailed the potential of the IWB in the classroom, described the pedagogical impact on both teachers and students, and analyzed the empirical evidence regarding learning and achievement. Their analysis showed the IWB can affect teaching and learning interactions, and the proficiency of the teacher is essential to mediating interaction with the students (Higgins et al., 2007).

The Schools Whiteboard Expansion (SWE) project described examples of new pedagogical practices and improvements to previous teaching methods. The IWB presentations that were prepared in advance served as a ‘script’ that reduced teachers’ cognitive load enabling them to focus their attention on listening to student talk. Further, teachers were better able to watch and guide the interactions between students, the content, and the IWB (Moss et al., 2007). These changes in teacher behavior led to a more personalized learning experience for students in whole-class setting. Improvements of previous pedagogy were also noted. For example, teachers’ use of IWBs facilitated shared space where teachers and students worked together (Moss et al., 2007). Consequently, the classroom transformed into an interactive learning environment and gains in student attainment were realized.

Glover et al., (2007) defined three approaches to interactive teaching. First, the supported didactic approach is a teacher-centered approach. According to Glover et al., (2007) “This teacher-centered approach was characterized by the teacher making use of the IWB but only as a visual support to the lesson and not as an integral strategy for conceptual development” (p. 10). In the study conducted by Glover et al. (2007), the teacher used a visual fraction wall to demonstrate equivalence. No other presentational techniques were used to bring about interactivity. The teacher followed a traditional direct instruction approach with minimal student activity. Glover et al., (2007) noted the effects on learning when the teacher used the didactic approach. Their research showed students viewed the IWB as a "novelty" in the lesson used to illustrate the content. In other words, the IWB was used for the attractive display of teacher presented content rather than for the student conceptual development.

The interactive approach differs from the supported didactic approach in that the "IWB is used to challenge students to think by using a variety of verbal, visual and kinesthetic stimuli" (Glover et al., 2007, p. 12). The interactive approach capitalizes on the affordances of the IWB that enable it to present information in a variety of ways through multi-sensory modalities and links technology and pedagogy. The study conducted by Smith, et al., (2005) aimed to ascertain the extent to which classroom interaction differed by comparing an IWB classroom to a non-IWB classroom. First, the results of their study showed that IWBs appear to have some positive impact on instruction compared to the classrooms that did not use an IWB for instruction. Second, Smith et al., (2005) concluded that changing from a supported didactic approach to a more interactive approach results in effective pedagogical practice when using the IWB as an instructional tool.

In the enhanced interactivity approach, the IWB is used as an integral part of the instruction (Glover et al., 2007). At the enhanced interactivity stage, there is an integration of technology, pedagogy, and learning styles. In this approach, lesson designs utilize the interactive capacity of the technology by combining concept and cognitive development strategies within the presentation. Glover et al., (2007) notes that during the enhanced interactivity approach, "the IWB can be used to prompt discussion, explain processes, and develop hypotheses or structure" (p. 13). In a study by Miller et al.,

(2004) average speeds were calculated during a lesson, and the presentation included an imported visual clip and ‘virtual manipulatives’ (on-screen objects that can be manipulated and used as a demonstration or understanding aid). Both students and teacher used the IWB throughout the lesson. The results were a highly interactive learning environment in which conceptual knowledge and cognitive development were supported by the use of the IWB (Miller et al., 2004). However, Miller et al., (2004) noted the enhanced interactive approach requires careful, sequential planning of lessons and concept development. Further, the enhanced interactivity approach requires that both teacher and student are fluent in using the IWB in order to obtain educational gains (Miller et al., 2004).

The IWB and Dialogic Learning

The research concurred that the IWB facilitates discussion between the students and teacher and serves as a mediating artifact that encourages dialogic learning (Murcia & Sheffield, 2010). In their study, Murcia and Sheffield (2010) compared discourse about science between IWB classrooms and non-IWB classrooms. Students and teachers used the IWB to discuss the solution to a problem and offer different points of view about a topic. The results of the study showed that the IWB classrooms positively affected the way the students talked about science (Murcia & Sheffield, 2010). In addition, Murcia and Sheffield (2010) noted the features that encouraged classroom discourse about the topics. Engaging and appealing interactive displays, interacting with online activities, and linking media in files were a few of the suggestions for using the IWB to encourage dialogue within the lesson design. The results of the study confirmed the use of the features on the IWB encouraged whole class substantive discourse. However, it is important to select the appropriate interactive resources and materials in order to support dialogic learning.

The study by Mercer, Warwick, Kershner, & Staarman, (2010) examined whether the IWB facilitated a shared dialogic space for discussion in a collaborative activity. Students were asked to write over the content presented on the screen. As a result, the use of annotation served as a fertile ground for discussion. The study by Warwick, et al., (2010) considered how students use the IWB when working in small groups while the teacher guided the activity of the students at the board from the back of the room. The research concluded the IWB can provide an environment and encourage the "creation of a shared dialogic space within which co-constructed knowledge building can take place" (Warwick et al., 2010, p. 350). The findings in this review establish a link between the use of the IWB and dialogic learning. However, more research is needed to exploit the potential of the IWB technology in order to encourage substantive discourse in the classroom.

The Interactive Whiteboards, Pedagogy and Pupil Performance Evaluation: An Evaluation of the Schools Whiteboard Expansion Project (London Challenge)

In the pivotal study, Evaluation of the Schools Whiteboard Expansion (SWE) Project, the British Educational Communications and Technology Agency discovered encouraging results for the regular use of the IWB in the classroom (Moss, et al., 2007). Funded by government programs and contributions from business, 275,000 IWBs were installed and used in British schools (Moss et al., 2007). The SWE project aimed to determine how to best use the IWB as an instructional tool in the classroom. The objective of the research was to assess the impact of the IWB use on teaching and learning, teacher/student motivation, and pupil attendance and behavior. It also examined the impact of the SWE's approach to teacher training on the effective use of the IWB (Moss et al., 2007).

In the SWE mixed methods research design, data were collected through cases studies, surveys, and statistical analysis of student performance. A key finding from the Moss et al., 2007) study was that the use of IWB can contribute to productive whole class teaching. Furthermore, teachers' reflection on their own current pedagogical practice can help identify how IWB can support and extend student achievement. Moss et al., (2007) observed when the teachers used the interactive features of the IWBs the students were better engaged with one another and their teachers. They also noted that teachers and students both enthusiastically welcomed the IWB. Additionally, they found the IWB was useful for small-group work and occasionally for individual work in the middle part of the lesson (Moss et al., 2007).

The results of the quantitative data analysis reported the impact of the IWB on student performance in classrooms equipped with IWBs. The data collection was conducted through the acquisition of student performance data from the National Pupil Database. The qualitative data analysis described differences in the use of IWBs between schools and subject areas. In addition, the qualitative data explored practices with respect to IWB use in elementary classrooms. The data collection was conducted in nine core-subject departments in the elementary level in London schools (math, science, and English).

The researchers matched the length of exposure of students taught with IWB with national progress test scores of student performance. The schools provided the student scores, and researchers recorded the length of time in which the students were exposed to the IWB. It is interesting to note that the intervention of IWB use in the classroom measured as a continuous variable rather than a binary measure of exposed or not exposed to the IWB. This method of measurement is different than the type used in previous studies where researchers compared IWB classrooms and non-IWB classroom (Smith, Hardman, & Higgins, 2006). The authors questioned whether the data would be able to detect the genuine effects of the IWB as an instructional tool if they collapsed the length of exposure data into dichotomous categories.

The results of the SWE project research confirmed that the length of time students were taught with an IWB is a major factor leading to student attainment gains. This appears to be an effect of teachers embedding IWB in their pedagogy, and the qualitative data strongly supported this interpretation. The average and high achieving students made greater progress than the low achieving students. However, gains for all levels increased once teachers had sustained experience in using the IWB as an instructional tool. The authors propose that the key is embedding the IWB in teachers' pedagogical practice and that this can only be achieved over time (Moss et al., 2007). When teachers used an IWB for at least two years, new patterns of teaching practice or new developments of established patterns were observable in the data, and the IWB became embedded in their pedagogy as a mediating artifact that increased interactivity within the classroom (Moss et al., 2007).

The SWE project described examples of new pedagogical practices and improvements to previous teaching methods. As a result of the prepared presentations on the IWB, teachers were better able to watch and guide the interactions between students, the content, and the IWB (Moss et al., 2007). These changes in teacher behavior lead to a more personalized learning experience for students in whole-class setting. Improvements of previous pedagogy were also noted. For example, teachers' use of IWBs facilitated shared space where teachers and students worked together (Moss et al., 2007). Consequently, the classroom transformed into an interactive learning environment and gains in student attainment were realized.

Prior Literature Reviews of Interactive Whiteboard Research

Prior literature reviews on IWBs described the direction of research in the use of the IWB as an interactive instructional tool and the factors and strategies that support effective classroom practice. Smith, Higgins, Wall and Miller (2005) summarized the early research conducted on the use of IWB in classrooms. They identified common themes throughout the research. Smith, et al., (2005) determined the IWB enhanced teaching and supported learning. Additionally, Smith, et al., (2005) discussed some of the problems and issues when using the IWB in the classroom which included ergonomic and technological concerns. They noted that most of the data collected in studies on IWB were usually in the forms of interviews, surveys and questionnaires. Conclusively, the research demonstrated favorable perceptions of students and teachers on the use of the IWB as an instructional tool (Smith et al., 2005). However, they cautioned that research on perception makes it difficult to assess the actual impact of IWB on teaching and learning and suggested broadening the scope of the educational research on IWBs (Smith et al., 2005).

The primary purpose of the review conducted by Glover, Miller, Averis, and Door (2005) was to analyze the interactive learning supported by the IWB. They sought evidence to understand the research on the management of change as the technology is introduced, the learning processes as teachers become more fluent, and the development of enhanced interactivity as a characteristic of effective pedagogy. Glover et al., (2005) concluded "that enhanced interactivity requires an understanding of the way in which both teachers and pupils gain from the use of the technology and demonstrate that there is a progression at all levels in learning to use the equipment and associated software to educational advantage" (p. 165).

The review by Higgins, Beauchamp and Miller (2007) served as an update to the previous reviews. They sought to identify the changes in classroom learning as it relates to the IWB and multi-modal teaching and learning. Further, the authors elaborated on the relationship between the IWB and dialogic learning. Higgins et al., (2007) detailed the potential of the IWB in the classroom, described the pedagogical impact on both teachers and students, and analyzed the empirical evidence regarding learning and achievement. Their analysis showed the IWB can affect teaching and learning interactions, and the proficiency of the teacher is essential to mediating interaction with the students (Higgins et al., 2007). However, a significant concern emerged from their analysis. Higgins et al., (2007) noted that "while the IWB may change the way that learning takes place, and that the motivation of teachers and students may increase, this may have no significant or measureable impact on achievement" (p. 220). In order for the potential of the IWB to be confirmed, more research should be conducted on assessing student achievement. Further, Higgins et al., (2007) claimed the success of the IWB in the classroom is dependent upon the pedagogical shift towards dialogic interactive learning.

As part of the seminal research report for the Schools Whiteboard Expansion (SWE) Project, the review of literature by Moss et al., (2007) aimed to examine existing literature on policy framework used to guide the implementation and use IWBs. This included a discussion on advocacy and initiatives along with an overview of sponsorship and funding. Of importance to this review is the analysis on the impact of IWB use in teaching and learning. Moss et al., (2007) focused on the determinants of IWB uptake and understandings of effective pedagogy. Concurring with prior literature reviews, Moss et al., (2007) state that the research base is small in scale and a more cogent representation of the potential of the IWB should be portrayed through rigorous methodology. Moss et al., (2007) further state that "few studies have tried to systematically explore the impact of IWBs on attainment" (p. 18) and the studies that attempted to connect the use of IWB and student attainment have failed.

Moss et al., (2007) discussed the potential of the technology and identified positive features of IWBs in teaching and learning. They found the multi-modal instructional approach afforded by the IWB supported a wide range of different learning styles and enabled teachers to model concepts in a variety of ways in order to deepen student understanding (Moss et al., 2007). Their analysis outlined effective features and usability factors when using IWB for instruction (Moss et al., 2007).

The prior literature reviews offer insight on the development and direction of research on the use of IWB in the classroom. First, it was established that teacher and student perceptions were favorable towards the use of the IWB as an instructional tool, but cautioned that this does not translate to the IWB having a positive impact on student attainment. Additionally, the prior reviews noted a pedagogical shift towards interactive teaching and dialogic learning as a means to improve student achievement when using the IWB as a mediating tool for instruction.

Summary

This review of the IWB literature aimed to examine how the features and manipulations of the technology are used during instruction and to identify the effective pedagogical characteristics that contribute to quality instruction. Additionally, research was explored in order to establish links between the use of the IWB and dialogic learning. The analysis of research provides the following considerations when designing presentations for the IWB.

First, the IWB can be used to direct learner attention. IWB features such as color, highlighting, and annotating can be applied to emphasize certain content or procedures. Additionally, the IWB can be used to present material through visual, aural, and kinesthetic modalities and the variety of features on the IWB allow for multiple representations of display. Also, the IWB screen can be touched and content objects can be moved. According to the literature, the kinesthetic modality afforded by the IWB had positive effects on student engagement (Lewin, Somekh, & Steadman, 2008). However, when designing instruction and using the IWB features it is important for the teacher to consider where and when the emphasis should be applied to direct learner attention. The function of the IWB must be considered in relation to the learning outcome. Furthermore, matching the appropriate representation and modality to the concept being taught is another important concern. Cognitive overload and split attention between content are two possible consequences of the misuse of the IWB features.

Second, this review has provided us with insights into the effective pedagogical practice when using the IWB for instruction. The use of the IWB in the classroom facilitates interactive learning. Even though the supported didactic approach follows teacher led instruction, the IWB affordances can prompt interactivity through discussion about the objects on the screen. The literature concurs the most effective approach is enhanced interactive. However, the design of instruction should consider the selection and sequence of content and interactivity carefully. There is merit to further exploring design approaches that address interactive teaching when using the IWB for instruction.

Finally, the most recent research emphasized the link between dialogic learning and the IWB. According to the research, there appears to be great potential for the IWB to serve as a mediating artifact to provide a joint reference for shared understanding between the teacher and student (Hennessy et al., 2007). Furthermore, the social presence afforded by the IWB features allows knowledge to emanate from student to teacher and student to class.

There are a number of principles from worked example research that can be supported by the use of the IWB. Learning from worked example instruction and using the IWB as an instructional tool both involve active participation from the learner. Students using worked examples are actively involved in the cognitive processes to determine the solution structure and rationale for choosing the appropriate procedure. Using colors to differentiate the various sub-goals necessary to solve multi-step problems could give students visual cues to help them remember problem solving procedures. In addition, visual aids can direct leaner attention to the structural features of the example. Interactive movement across the screen can be used as a form of visual representation.

The interaction allows students to be more actively engaged and visualize the mathematical procedures needed to obtain the solution. The affordances of the IWB can support worked example instruction through various levels of interactivity and can be used to enhance the learning environment through use of multiple representations.

Further, the research on worked examples and IWBs maintain discourse as an effective approach by which students are able to make meaning and develop understanding of the instructional content. Worked example research indisputably supports the importance of self-explanation when learning from worked example instruction. It would seem plausible that there exists a relationship between worked example self-explanations and the affordances of the IWB used to support dialogic learning.

Chapter 3

Methodology

The focus of this research was to explore whole class dialogue and student self-explanation when applying the supported didactic, interactive, and enhanced interactive pedagogical approaches in conjunction with the affordances of the IWB using worked example instruction for a Calculus II class. The research addressed the following questions:

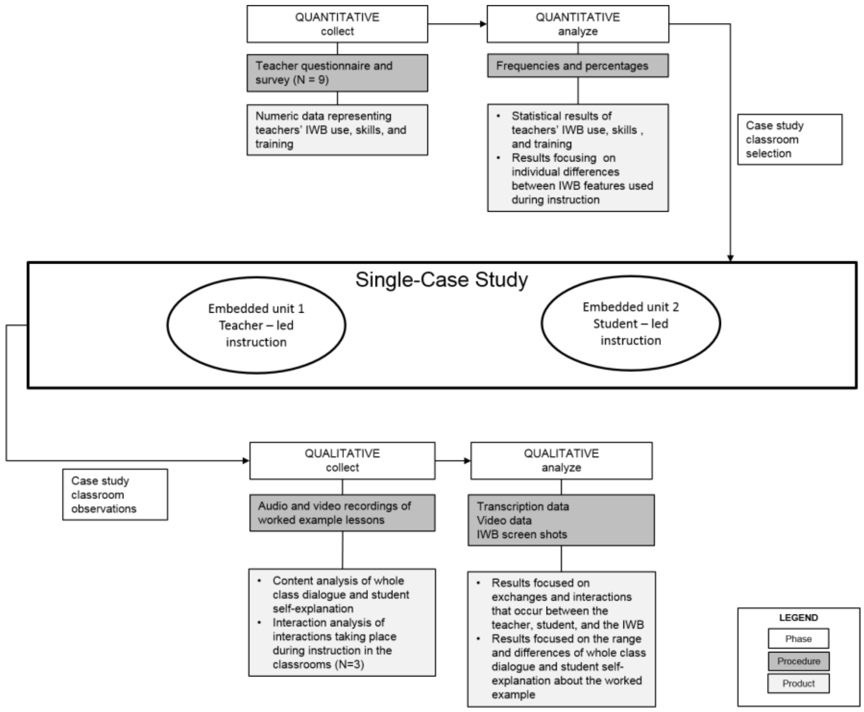
1. How do teacher-led and student-led IWB visual presentation of procedural and conceptual aspects of worked example instruction affect classroom interaction?
   a. In collaborative whole class instruction?
   b. In student's self-explanation of content in worked examples?
2. In what ways do different IWB features and pedagogical approach affect worked example instruction?

Study Design

This study used an embedded single-case study design. According to Yin (2003) the term, "embedded case study," typically refers to a single-case study that involves more than one unit of analysis. The embedded single-case study was utilized to develop explanatory inferences about key aspects of the use of the IWB for worked example instruction. For the purpose of this research, the single-case study investigated discourse in a classroom using the IWB for worked example instruction. The sub-units of investigation 'embedded' in the case were observations from both teacher-centered and student-centered worked example presentations. The sub-units are described in detail later in this chapter.

It is important to mention the development of methodology selected for this research. Initially, the study was designed as a mixed-method embedded single-case study. Under this consideration, quantitative data would have been used to identify how current Algebra 1 teachers were implementing IWBs in their classrooms and subsequently develop a database of teachers from which to select a single-case study classroom. However, low teacher participation in the survey resulted in a lack of quantitative data from the Algebra 1 teacher survey. Thus, the original design which included a detailed report of IWB usage by Algebra 1 teachers in the district was abandoned. As a result, the limitation generated a need to change the study methodology to an embedded single-case study design. Another deviation from the originally proposed study was the subject content of the worked example instruction. Based on the case-study teacher's request, data were collected in a Calculus II classroom. While change in content may not directly affect the study methodology, it does affect the context under which the study was conducted.

Figure 3-1 Embedded Single Case Study Design: Design Phases, Procedures, and Products of the Research Methodology.



Setting and the Case Study Teacher. This study was conducted in an urban, mid-sized school district in the Southeast using the sole respondent to the teacher survey as the case subject. This teacher agreed to participate but asked that data be collected in her AP Calculus II class, to which the researcher agreed. Video and audio recordings were conducted in the classroom during three lessons that used the IWB to present worked example instruction in a whole class setting. The IWB used in the study is the SMARTBoard™ Interactive Whiteboard wired to the network through a desktop teacher computer. A projector mounted on the ceiling connected to the computer displays the worked example lesson on the screen in the front of the room.

Participants

This study of the connection between the use of an IWB for worked example instruction and dialogic learning was conducted in a large urban school district in central Kentucky. The teacher survey participants were selected because they were Algebra 1 teachers and had access to an IWB in their classroom. The number of survey participants was a sample of 115 teachers from 17 middle and high schools. The qualitative sample consisted of a voluntary Algebra 1 teacher who showed an interest in participating in the study under the condition that the study was conducted in a Calculus II classroom. The case-study classroom consisted of 25 high school juniors and seniors. Prior to the study, school district and university consent protocols were followed. All study participants were informed of the research process and assured confidentiality. Pseudonyms were applied to mask all participants' names, though gender identification was preserved.

Procedures and Instruments

Case studies, by definition, have multiple sources of data (Yin, 1993, p. 29). For this study, video recordings of the IWB instruction, classroom observations and IWB screen recordings provided qualitative data the researcher collected. These data were used to document the different interactive features and affordances of the IWB and to capture the interactions with the whole class as well as individual student's self-explanations or dialogues during the worked examples with IWB instruction. These data were also used to examine student understandings of the problem type presented through the analysis of student self-explanation about the worked example. An initial survey of math teachers in the school district was also distributed as part of the recruitment process. Using this blend of quantitative and qualitative data collection methods, the study instruments were designed to investigate IWB implementation in actual classrooms through a series of three stages.

The stages began with the administration of the teacher survey and questionnaire (Appendix B) to the Algebra 1 teachers in the district. The survey was adapted from a study conducted by Türel and Johnson (2012) and asked similar questions pertaining to teacher participants' demographic data and inquiries about the use of the IWB in Algebra 1 classrooms.

The survey consisted of six open ended questions and 18 multiple-choice Likert scale items to determine demographic data and teachers' usage statistics to provide a better understanding of the main dimensions of IWB use including instructional effects of IWB and the functions of the IWB during a lesson. The survey was designed to generate numeric data representing Algebra 1 teachers' IWB use, skills, and training. However, due to low survey participation, the data was not statistically analyzed.

The researcher contacted the district superintendent's office for permission to conduct the study. Once permission was granted, the researcher attended a district Algebra 1 professional development training to explain the research study and invite the teachers to participate. The researcher informed the Algebra 1 teachers that they could expect a forthcoming email containing more information about the study and the link to the online survey. The email contained information about the study including information on informed consent by the participants. After reading the information about the study, the participants were asked to follow a link to the online survey (see Appendix B). The first part of the survey contained information about the study and informed consent. The participants agreed to the information outlined in the informed consent statement by completing and submitting the online survey. The last question on the survey asked the participants to include their name if they were willing to volunteer for a classroom observation and video and audio recordings. If a survey participant did not volunteer, his or her responses were anonymous. The participants provided their names and contact information if they volunteered as a case-study classroom. This information was not associated with the data from the rest of the survey.

Of the 115 potential participants, nine responded to the survey (8% response rate). On the survey, seven teachers indicated interest in being a case-study classroom. However, when the researcher contacted the teachers to confirm participation, only one teacher volunteered to participate. The reasons for declining to be a case study classroom consisted of end of year activities and other class time interruptions. The volunteer teacher offered to participate under the condition that the research be conducted in an AP Calculus II class.

The case study selection criteria included the teacher's willingness to participate, access to IWB technology, and experience with the IWB as an instructional tool. The goal was to ascertain teachers who are familiar with the IWB features and affordances and can apply the methods and strategies used during the interactive pedagogical level assigned to the worked example lesson presentation. The case-study teacher participant had access to IWB technology but had only used the IWB intermittently for worked example instruction and subsequently had minimal experience with the features and functionality of the IWB.

During the second stage of the recruitment and preceding data collection, the researcher met with the participating teacher and provided a tutorial of the functionality and use of the IWB. The researcher demonstrated how to use the designated features that were to be implemented during the lesson. Subsequently, the teacher practiced using the IWB on a worked example lesson similar to the lessons to be conducted during the study.

The teacher provided information about the study and the informed consent process to the AP Calculus II students before the classroom observations were conducted. After reading the information about the study, the student participants were asked to submit the proper form (Assent or Consent) dependent upon the age of the individual (see Appendix D). The first part of the letter contained information about the study and informed consent. The participants agreed to the information outlined in the informed consent statement by completing and submitting the appropriate form. Guardian signatures were obtained for those students under the age of 18. If a student participant did not consent, his or her participation was eliminated from the data set. Pseudonyms were applied to mask all participants' names, though gender identification was preserved

The researcher met with the case study teacher prior to the worked example lessons for a training on the interactive features of the IWB. The teacher had experience using the pens to display the worked example but needed training on some of the interactive features such as clone, hide and reveal, and different pen types. The training lasted approximately 30 minutes and the teacher was able to use the interactive features successfully.

The third phase of the research was the actual classroom implementation of the three classroom teaching approaches using the IWB. Audio recordings captured the discussion between and among students and teacher during the worked example presentation. Concurrent with the audio recordings, the video recordings captured the interactions between and among the students, the teacher, and the IWB in each of the presented lessons. By considering both the audio data and the video data of the lesson, the research described and characterized the dialogue and interactions that occurred during instruction to better understand the mediating effects (if any) of the IWB during the worked example instruction.

The first two lessons were teacher-centered (supported didactic and interactive) and the third lesson was student-centered (enhanced interactive). An example of the presentations used for each lesson is found in Appendix C. Each presentation included three to five review problems from previous chapters covered throughout the course of the school year. The transcripts and video recordings highlighted connections between what was said and what happened in the classroom and described the extent to which the different interactive pedagogies encourage or discourage class discussion about the worked examples. Two whole-class video recordings were used for each worked example lesson.

Transcripts of whole class discussion were developed from the recordings of each worked example lesson and used for content analysis of the dialogue between and among the students and the teacher about the structural and procedural solution steps of the work example. In addition to the transcripts, videos captured the IWB screen during the worked example presentation at each interactive level. The videos captured what was happening during the worked example presentation and depicted moments of interaction between the student, teacher, and which features were in use on the IWB. These data would support an analysis that would focus on the range and number of interactions taking place during instruction, the forms of dialogic interaction about the worked example, and students' explanations of the presented problems for each of the three lesson presentation types.

Analysis

The sub-units of analysis embedded in the single-case study classroom consisted of observations during both teacher-centered and student-centered lesson designs. Each lesson was categorized based on the level of interactivity used for the worked example presentation. Three categories of interactivity were implemented: supported-didactic, interactive, and enhanced interactive. For the purpose of this study, the levels of interactivity were assimilated based on Glover's definitions of interactive pedagogies for the IWB (Glover, et al., 2007). As shown in Table 3.1, the supported didactic group emulates teacher-directed instruction using minimal interactive features of the IWB. The features used were limited to simple dry erase, overwrite, and color. The IWB functioned only as a visual support of the worked example presentation. The interactive group implemented teacher-led instruction but employed higher levels of interactivity when using the IWB for the worked example presentation. The teacher used a variety of IWB visual and kinesthetic features during the worked example instructions. These included IWB features such as highlight, movement, and hide or reveal. The final group, enhanced-interactive, used student-led instruction facilitated by the teacher and included high levels of interactivity through use of the IWB on-screen features. Specifically, this group used on-screen objects that can be manipulated by the teacher and students during the worked example instruction. Table 3-1 describes the interactive pedagogical levels and IWB features.

Table 3-1

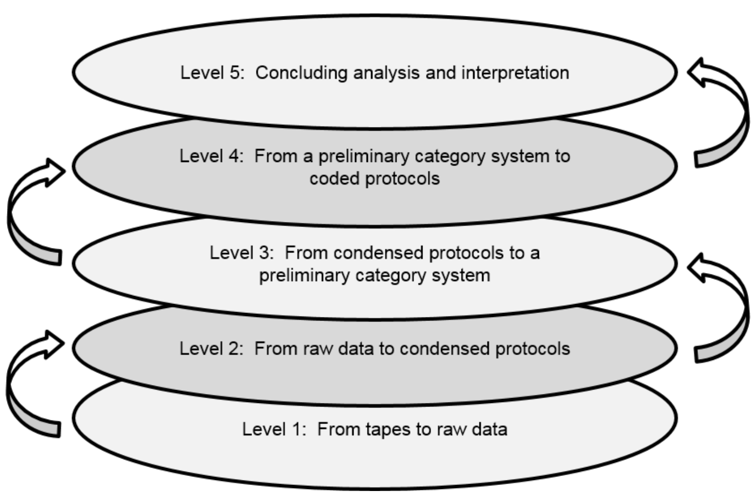
Interactive Pedagogical Levels and IWB Features.

Teacher-centered instruction		
Interactive pedagogy	Description	IWB features used
Supported Didactic	The IWB serves as a visual support to the lesson and is only used by the teacher.	Write or draw Overwrite Color
Interactive	The IWB is used by the teacher to present information in a variety of ways through multi-sensory modalities	Drag or drop Hide or reveal Highlight Movement or animation Use of internet – non interactive or video Use of internet – interactive or game IWB resource gallery Use of hyperlink within lesson
Student-centered instruction		
Interactive pedagogy	Description	IWB features used
Enhanced-Interactive	The IWB is used by student pairs to present the worked example. The same features used in the interactive method are also used in this category. However, the difference is that both teacher and students access and use the IWB during instruction under the enhance-interactive pedagogical method.	Drag or drop Hide or reveal Highlight Movement or animation Use of internet – non interactive or video Use of internet – interactive or game IWB resource gallery Use of hyperlink within lesson Student use

Content analysis was used to investigate the dialogue and interactions that took place in the classroom during instruction for each interactive pedagogical group. Content analysis is a methodical examination of the contents of a qualitative data set for identifying patterns or themes (Schilling, 2006). Mayring (2000) defines qualitative content analysis as "an approach of empirical, methodological controlled analysis of text within their context of communication, following content analytic rules and step by step models, without rash quantification" (p. 2).

This study applied the qualitative content analysis spiral (see Table 3-2) developed by Schilling (2006) in order to examine the range and differences of exchanges and interaction that occur between the teacher, the students, and the IWB. The spiral was used to guide the design process of qualitative analysis. The visual representation provided a way to collect, analyze, and report qualitative data that was systemic and transparent.

Figure 3-2 Iterative Steps to Qualitative Content Analysis.



The first level emphasizes the importance of defining explicit rules when transcribing audio to written text. To preserve the authenticity of the whole-class discussions, the audio recording transcripts were speech focused and disregard audible behavior unless it is pertinent to the worked example instruction. For example, the sound of a student coughing during the lesson would be disregarded during the transcription. However, content and speech will be analyzed to include pauses, slips of tongue, or other sounds that may add information to better understand content of whole class dialogue. To complete the first level of analysis, a general review of the audio and video was analyzed to obtain an idea of the overall scope of the data. To secure data quality, names of teacher and student participants were replaced with descriptive terms and a coding scheme developed to compare the differences of whole class discussion between the interactive pedagogical levels.

The second level of the content analysis spiral articulates definitions and rules in order to condense the transcriptions to paraphrases and preserve the essential contents of the data. To begin the process of paraphrasing, the researcher should define initial categories to use when classifying the paraphrases. This study examined the whole class dialogue during a worked example presentation on the IWB while considering the types of interactions between and among the teacher, the students, and the IWB. Therefore, the initial categories for this study considered references to the structural features of the worked example, discussion about the content of the worked example, and the interactions between and among the teacher, the students, and the IWB.

Schilling (2006) recommends that during the second level of the content analysis spiral, the researcher should define the boundaries of unitizing the text. For the purpose of this research, the units of analysis considered single words, phrases, and half or full sentences along with the audible sounds and pauses as defined earlier in order to capture the dialogue and interactivity within the whole class discussion about the worked example presentation on the IWB.

To condense the paraphrases, the researcher generalized the paraphrases into statements thus representing common themes that occurred during the whole class discussion about the worked example. This included the consideration of context when conjunctions were used in the dialogue. Schilling (2006) stresses the importance of considering the purpose and use of conjunctions, such as “and”, “or”, and “but,” when defining the units of analysis. For this study, conjunctions that denote a causal relationship between the structure and content of the worked example are considered a single statement. Otherwise, the conjunction is dismissed and the data is recorded as two single statements.

The third and fourth levels of the content analysis spiral are designed to develop a structured category system and protocols that can be used to codify the qualitative data. As mentioned previously, the three preliminary categories analyzed are talk referring to the structural features of the worked example, discussion about the content of the worked example, and the interactions between and among the teacher, the students, and the IWB. Chi, et al., (1989) examined the structure and content of student explanations about worked example by considering explanations “that ‘Good’ and ‘Poor’ students produce while studying worked-out examples” (p. 158).

This study used a similar approach to analyze the whole class discussion about the structural features and content of the worked example instruction (see Table 3-3). In addition, the protocols established by Chi, et al., (1989) guided the analysis of student self-explanations obtained during the worked example lessons. Both whole class discussion and self-explanations will be analyzed for student understanding of the conceptual structures and solution procedures of the worked example as evidence of schema formation or elaboration of content presented (see Table 3-3).

Table 3-2

Structural Analysis: Whole class discussion and student self-explanation

Chi, et al. Protocols	Research Study
Refine or expand the conditions of an action	Are there differences between the number and types of refinements and expansions made by students during whole class discussion and the features and affordances used on the IWB during instruction?
Explicate or infer additional consequences of an action	Are there differences between the number and types of student responses that infer additional consequences for choosing a particular solving strategy and the features and affordances used on the IWB during instruction?
Impose a goal or purpose for an action	Are there differences between the number and types of student responses that explain the purpose for using a particular solving strategy and the features and affordances used on the IWB during instruction?
Give meaning or purpose to a set of quantitative expressions	Are there differences between the number and types of student responses that give meaning and purpose to the quantitative expressions displayed and the features and affordances used on the IWB during instruction?

Haldane (2007) examined technology-enhanced whole class instruction by considering “the action, the person(s), and the mediational means in a holistic manner” (p. 262). Three questions were used to guide the analysis of interactivity between teachers, students and the medium of the IWB:

1. Who is interacting with whom (or what)?
2. How are they interacting? (What are they doing?)
3. What is the effect on whole class discussion?

This study used a similar approach to analyzing teaching and learning within the interactive learning environment during worked example instruction (see Table 3-4)

Table 3-3

Interactivity Analysis: Whole class discussion

Haldane (2007) Analysis Questions	Research study
Who is interacting with whom (or what)?	Is there a difference in the number of student and teacher interactions and verbal exchanges about the worked example between the pedagogical levels?
How are they interacting? What are they doing?	Is there a difference in how the students and teacher interact and discuss the worked example between the pedagogical levels?
What is the effect?	Is there a difference in substantive talk about the worked example between the pedagogical levels?

Multiple methods of data analysis were utilized in this study. Triangulation of the data occurred by analyzing data from the teacher surveys and audio and video transcripts of the worked example lessons. According to Creswell (2011), triangulation, or convergent design, occurs "when the researcher collects and analyzes both quantitative and qualitative data during the same phase of the research process and then merges the two sets of results into an overall interpretation" (p. 77). The quantitative data from the district survey was analyzed to compare the teacher's expertise against her district peers. The data obtained on the frequency of IWB use during worked example instruction were analyzed. Frequency counts were used to identify conceptual and procedural processes of the worked example supported by the technology. Qualitative data from all three worked example presentations were analyzed using content analysis to identify the effect of the IWB on whole-class dialogue. The same data were analyzed using open coding for repeated or related themes. Triangulating the various sources of information gathered from the audio and video records and IWB screen shots during worked example lessons assisted in the validation of the study recommended by Yin (2003).

Chapter 4

Findings

Introduction

In this chapter I present the major themes that were identified during the analysis of the data. The Findings Part I section contains relevant contextual information about the case study teacher, including teaching history, content area focus, and general perception of IWB use in the classroom. Information germane to the case study classroom such as demographics, physical classroom environment, and student use of the IWB concludes Part I of the findings. The Findings Part II section addresses the research questions through the presentation of data related to both teacher and student IWB use and dialogic patterns in the classroom discourse organized into themes and categories. A summary of the findings concludes the chapter.

Findings Part I: The Case Context

The Case Teacher: Ms. Monica Stepps

Monica Stepps (pseudonym) is a National Board Certified Teacher (NBCT) at a large urban high school in central Kentucky where she teaches AP Calculus and Algebra. She received a Bachelor's degree in Education at a private liberal arts university and received a Master's degree with an emphasis on teaching mathematics. She was a math teacher for 13 years at the time of the data collection.

During her interview, she noted that beyond her involvement in her classroom and school, Monica was one of seven "teacherprenuers" selected nationally by the Center for Teaching Quality (CTQ). CTQ is a national nonprofit organization comprised of expert educators who collaborate and serve as teacher leaders, called "teacherprenuers." The teacher leaders develop and market a system to spread knowledge about 21^{st}-century teaching and learning and provide applicable solutions to classrooms across the nation. Monica's involvement with CTQ focused on innovative ways to implement the Common Core standards across the state of Kentucky.

Monica identified herself as being comfortable with technology. She had experience with graphing calculators, computers, and other types of teaching technology tools, such as blogs and web-based calculator applications. Monica reported she was most comfortable using the pens to display the worked example instruction on the IWB. While she was aware of the advanced interactive applications of the IWB, such as hide and reveal, she had not received formal training on how to use or apply the features in an instructional lesson. During the training session prior to data collection, Monica learned how to use some interactive features such as clone, high and reveal, and different pen types. She was able to use the interactive features without any difficulty.

The Case-study classroom: AP Calculus II

The embedded single-case study was conducted in Ms. Stepps AP Calculus classroom. Pseudonyms mask all participants' names, although gender identification has been preserved. There were 25 students in the classroom ranging in age from 16 to 18 years old. Of the 25 students, eight were female and 17 were male. The classroom seating was arranged in a traditional fashion with the IWB board in the front center of the room and the chairs aligned in rows. There were a total of 30 desks. Dry-erase boards surrounded the IWB on both sides. All students had a clear view of the boards which projected the teacher computer onto the screen. The teacher computer was located in the front of the room and did not block student view of the boards.

Previous classroom use of the IWB in Ms. Stepps' classroom. During the initial meeting between the researcher and Ms. Stepps, she reported she would ask students to display their homework problems on any of the available boards in the front of the room. Routinely, once or twice a week, she would assign four to six problems to display on the boards in the front of the room. Students did what was instructed and selected a board to display their assigned worked example.

Several inferences follow from this initial discussion. First, a teacher-centered, didactic instructional model seems to be the basis for the pedagogical culture previously established in the case-study classroom. Even though she has had the IWB in her classroom for five years, and her self-reported comfort with technology, there is little evidence of teacher use of the interactive whiteboard advanced features. Second, this approach also implies that within the environment of the case study classroom, the interactive features of IWB were used very little by the students to support student learning from worked examples, through interaction or dialogue, with either whole class or individual student's use.

Findings Part II: Research Questions

Shilling's (2006) model for content analysis was used to process and identify themes and categories from the audio and video transcripts (see Table 4-1). The process involved combining audio transcripts with corresponding screen shots to capture the use of the IWB during the worked example presentation. The researcher read the data several times to determine a preliminary category system and define common themes to apply to a coding system. The research questions are addressed in the following sections with findings from the themes and categories that relate to each research question. The themes help to understand how the IWB was used during the teacher-centered and student-centered instructional conditions and to identify if a relationship exists between worked example self-explanations and the affordances of the IWB used to support dialogic learning (See Table 4-2).

Table 4-1

Content Analysis – Themes and Categories

Themes/Subthemes	Definition
Turn type	Transition relevant places (Sacks, 1974) were observed at the end of the member contribution for that turn
Information	Talk containing relevant information about the worked example
Question *Answer*	Talk posing a question Talk answering a question
Repair	Talk correcting misinformation or a wrong answer
Confirmation	Assurance of concept understanding or of a correct answer given
Content of talk	Dialogue between participants pertaining to the worked example
Conceptual	Talk about the worked example including connections and inferences providing a heuristic view of the math concept
Procedural	Talk about the process of steps taken for problem solution
Introduce	Introductory talk pertaining to the worked example
Test-taking advice	Information about AP exam test-taking strategies
Engage prior information	Talk encouraging participants to reflect on prior knowledge
Agreeance	Agreement between participants
Correction	Talk correcting a procedural error
Type of Explanation	The reason for which the talk occurs under a given instructional context
Refine or expand the conditions of an action	Talk that defines the parameters under which a procedural step can be taken
Explicate or infer consequences	Talk that extrapolates outcomes based on the selection of a particular problem solving strategy
Impose goal or define purpose of action	Talk that explains the purpose for using a particular solving strategy
Give meaning or purpose to a set of quantitative expressions	Talk that provides numerical meaning to quantitative expressions

Table 4.2

IWB Feature Correlation with Worked Example Instruction

Themes/Sub-themes	Definition
Features	The IWB features used during the worked example presentation
Action – no board	Worked example instruction supported by demonstration or illustration without using the IWB
Reference	The participant refers to the IWB during instruction, but no IWB features are used
Write or draw	The participant uses the pen to write or draw on the IWB board
Color	The participant changes colors during a worked example presentation
Overwrite	The participant annotates words, pictures, or problems displayed on the screen
Highlight	The participant uses the highlight pen
Hide or reveal	The participant uses an IWB feature to hide or reveal a problem step or concept
Technical difficulties	The participant experiences technical difficulties with the IWB
Purpose	The reason for which the IWB was used during the worked example presentation
Conceptual	The IWB is used to display connections and inferences providing a heuristic view of the math concept
Procedural	The IWB is used to display the procedure steps taken for problem solution
Direct Attention	The IWB is used to direct student attention to worked example presentation
Advice	The IWB is referenced for AP Exam test-taking strategies
Engage prior knowledge	The IWB is used to engage prior knowledge of the participants

Note also that the themes that emerged and are noted above were embedded in the three observation conditions that comprised the data collection procedures. Each lesson supported a different level of IWB interactivity: supported didactic, interactive, and enhanced interactive

Three Observation Classroom Conditions:

Supported Didactic, Interactive and Enhanced Interactive.

Discussion of Frequencies

Research on the IWB and worked examples describes discourse as an effective approach by which students are able to make meaning and develop understanding of the instructional content. The primary goal of this study was to better understand the effect of the IWB visual presentation on collaborative whole class dialogue and student self-explanations of content in the worked example.

Table 4-3 shows the frequencies of conceptual and procedural talk during each of the three teaching conditions as indicated by the transcripts from each lesson. The frequencies and percentages are listed for each teaching condition since the total number of codes varies greatly from one lesson to another.

Table 4-3

Teaching Conditions: Conceptual and Procedural Dialogue

	Teaching Condition					
Type of Talk	**Teacher Led – 1**		**Teacher Led – 2**		**Student Led**	
Talk about the worked example including connections and inferences providing a heuristic view of the math concept (Conceptual)	47	32%	75	27%	28	27%
Talk about the process of steps taken for problem solution (Procedural)	102	68%	201	73%	76	73%
Total	149		276		104	

Note: The frequencies and percentages of the conceptual and procedural dialogue in each teaching condition during worked example instruction.

The patterns of talk that emerged under all three teaching conditions predominantly consisted of procedural explanations about the worked example. In the subject of Calculus there is a connectedness between several procedures and some strategic knowledge of when to use procedural or conceptual knowledge to accomplish the mathematical task at hand efficiently. For example, a student should have procedural knowledge of how to take the derivative of a function at a given value. Further, the student should have conceptual knowledge that the derivative of a function at a given value represents the slope of the tangent line at that point. Connections between the two areas of knowledge result in the student's ability to know that when asked for a tangent or normal, a derivative will be necessary. At the minimum, there will be one procedure step to solve for a derivative. However, given the problem types in AP Calculus II, there are more likely to be multiple procedure steps to find the derivative. Therefore, the dialogue about the worked example will be more procedural based than conceptual.

Table 4-4 shows the frequencies of use of the IWB as a mediating tool during each of the three teaching conditions as indicated by the transcripts from each lesson. The frequencies and percentages are listed for each teaching condition since the total number of codes varies greatly from one lesson to another.

Table 4-4

Purpose of IWB Use in Teaching Conditions

	Teaching Condition					
Purpose of IWB Use	**Teacher Led – 1**		**Teacher Led – 2**		**Student Led**	
The IWB is used to display connections and inferences providing a heuristic view of the math concept. (Conceptual)	3	5%	22	18%	15	20%
The IWB is used to display process of steps taken for problem solution (Procedural)	61	94%	82	67%	57	77%
The IWB is used to direct student attention to worked example presentation (Direct Attention)	1	1%	18	15%	2	3%
Total	65		122		74	

Note: The frequencies and percentages of the purpose of IWB use found in each teaching condition during worked example instruction.

The nature of the content influenced the reason the IWB was used at any given time. While calculus uses an intuitive approach to problem solving, problem-types require multiple procedure steps to obtain the solution. The display of steps provides a rationale for decisions made during problem solving and justifies the solution. This results in the IWB being used to display procedural steps more than the other purposes discovered.

This study used a similar approach established by Chi, et al., (1989) to analyze self-explanations obtained during the worked example lessons. Transcripts from all three teaching conditions as those used for interaction patterns were analyzed. The frequencies and percentages are listed for each teaching condition since the total number of codes varies greatly from one lesson to another. Table 4-5 below shows the types of explanations verbalized as presenters and students discussed the worked example presented on the IWB.

Table 4-5

Types of Verbalized Explanations

	Teaching Condition					
Type of Explanation	**Teacher Led – 1**		**Teacher Led – 2**		**Student Led**	
Refine and expand conditions of an action	26	23%	43	27%	19	21%
Explicate or infer consequences	16	14%	34	21%	20	22%
Impose a goal or define a purpose of action	12	11%	32	20%	20	22%
Give meaning or purpose to a set of quantitative expressions	57	51%	53	33%	31	34%
Total	111		162		90	

Note: The frequencies and percentages of the types of explanations found in each teaching condition during worked example instruction.

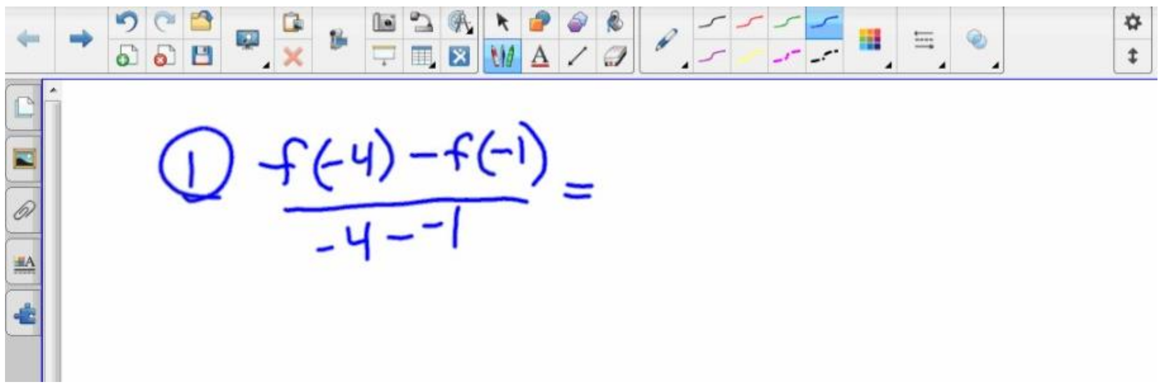
In all three teaching conditions, a majority of the explanations given were to provide quantitative values for expressions used when solving the problem. This means a majority of the time numerical answers or simplified expressions were provided to explain the problem step solution. This is a result of the number of procedure steps necessary to solve the worked examples presented during the instruction.

Discussion of observations

Data for this study were gathered during three classroom observations, two that focused on teacher-led class sessions using the IWB and one that focused on a student-led session using the IWB. The two teacher-led conditions are termed *supportive didactic* and *interactive.* The student-led condition is termed *enhanced interactive*. For each condition, I provide data regarding patterns of talk, use of the IWB during worked example instruction, and types of explanations provided by teacher and students.

Supported didactic teaching condition. Under the supported-didactic condition, the pen and overwrite were the only presentation techniques used to bring about interactivity. The overwrite feature was used once throughout the lesson. The worked example problems were not included in the presentation design. Thus, the teacher had to write each problem on the board using the pen (see Figure 4-1)

Figure 4-1. Teacher-Led Supported-didactic Condition (IWB Screen Shot).



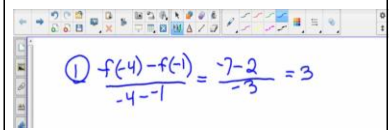
Monica introduced the first worked example to the class by asking a conceptual question about rate of change (see Figure 4-2.) She was standing in front of the board, partially obscuring the board information, facing the class.

Figure 4-2. Teacher-Led Supported Didactic Teaching Condition (Excerpt 1)

Talk	Board Usage
Teacher: "Okay. Now here is my question – when you are finding average rate of change do you use calculus?" **WC:** "No" **Teacher:** "No. When do you use calculus?" **WC:** [Crosstalk – students calling out answers] **Teacher:** **"**Instantaneous rate of change and?" **S2**: "Rate of…" **Teacher**: "….Instantaneous rate of change and average value." **Teacher:** "Average value is different from average rate of change. Does everybody understand the difference? Okay. It is really important. Sometimes we get those three things mixed up."	n/a

Next, she grabbed a pen from the IWB and began to write the example on the board followed by the subsequent procedural steps (see Figure 4-3). The IWB screen shot steps that accompanied the above classroom talk are shown below. All of these steps were recorded by the teacher as students called out responses to her questions.

Figure 4-3. Teacher-Led Supported Didactic Teaching Condition (Excerpt 2)

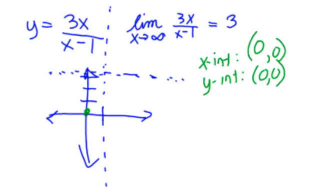
Talk	Board Usage	IWB Visual Display
Teacher: "So how do we do this like, for number one, if I am trying to find the average rate of change? What would I do?"	Write problem on board with pen	
S2: "f (-4) minus f of negative…."	Write procedure steps on board with pen	
Teacher: "f (-4) minus f (-1) all over…"		
Teacher: "So what would be f (-4)?"		
S2: "f (-4) is …2...uh…negative 7."		
S3: "Negative 7."		
Teacher: "Minus?"		
S6: "Negative 3."		
S2: "I think 2."		
Teacher: "All over?"		
S3: "Negative 3, which equals…"		
Teacher: "Yes, 3."	Write solution on board with pen	

During the dialogue, Monica faced the board to write the procedural steps on the IWB board. She confirmed the correct answer verbally while completing the procedure steps to finish the problem and then restated the solution.

As the lesson proceeded, patterns of talk began to emerge. First, during the first lesson, 68% of the questions asked by the teacher to the students focused on completing the procedural steps for the worked example solution. Second, when the teacher posed a question to the whole class, she did not designate specific students to answer. Rather, students randomly called out answers. Third, she would sometimes complete or prompt the answer rather than using any wait time for students to work through the procedures for a solution. During these exchanges, the teacher would use the board to display the procedural steps.

Another example of procedural talk occurred later in the lesson. In this scenario, the teacher writes the procedure step as the student responds with the answers (See Figure 4-4).

Figure 4-4. Teacher-Led Supported Didactic Teaching Condition (Excerpt 3)

Talk	**Board Usage**	**IWB Visual Display**
Teacher: "So, how do we find the X and Y intercepts?" **S3**: "Uh, where x is 0 and y is 0" **Teacher:** "Yes, so is Y ever going to be equal to zero?" **S3:** "Yeah it's just at (0, 0)." **Teacher:** "Zero, yep… " **S4:** "And it's also the y-intercept at (0, 0)." **Teacher:** "Yeah, so okay. There are my intercepts."	Writes x-intercepts with pen Writes y-intercepts with pen Plots point on graph with pen	

Dialogue that expanded or inferred conditions about the worked example composed less than a third of the talk with students during the lesson as seen in the dialogue below (see Figure 4-5).. Monica led a discussion about the conditions under which a point is considered a critical point on a graph. During the explanation, the teacher stood in front of the IWB partially blocking the information on the screen.

Figure 4-5. Teacher-Led Supported Didactic Teaching Condition (Excerpt 4)

Talk	**Board Usage**
Teacher: "X-coordinates are the critical points. What is the critical point?" **S5:** "Uh, max or min." **S5:** "It's what you get when the derivative changes." **S4:** "Yeah, yeah, yeah, critical point." **Teacher:** "Max or min. Yea, yea, yes. Critical point. Right. It is where the derivative changes signs. Critical point gives you – critical point is a possible extrema. Okay?"	n/a

Similar to the lesson introduction, most conceptual dialogue was conducted with the teacher in front of the board talking to the whole class. There was one instance where the teacher referenced the worked example on the IWB for conceptual purpose.

During a discussion about asymptotes and their position on the plane, Monica stood to the side of the board as she referenced the displayed graph (see Figure 4-6)

Figure 4-6. Teacher-Led Supported Didactic Teaching Condition (Excerpt 5)

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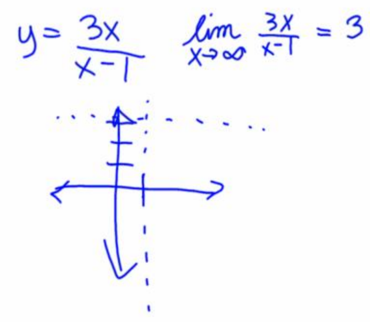
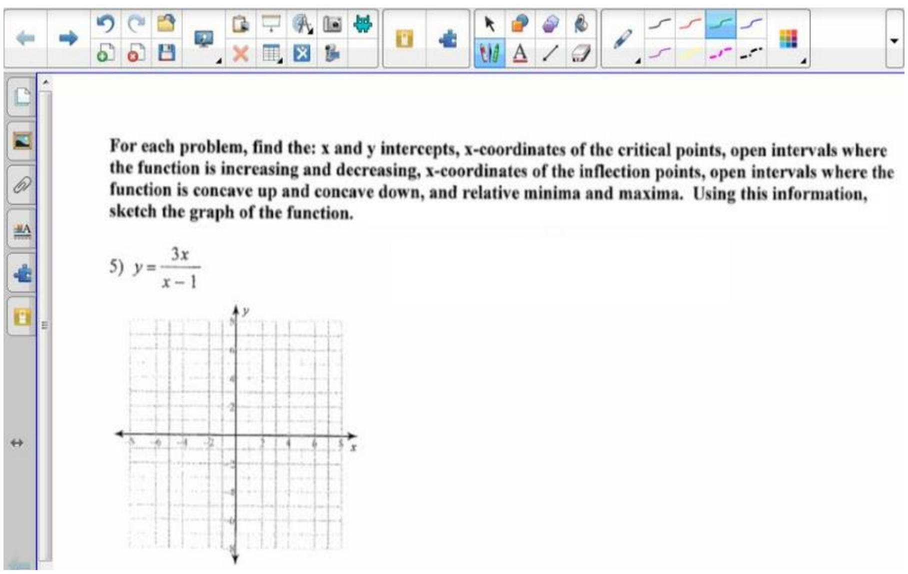
Talk	Board Usage	IWB Visual Display
Teacher: "Now remember a horizontal asymptote does not work the same as vertical asymptote where it doesn't, yes you're – you're allowed – you could possibly cross the horizontal tangent. It is not like you're not allowed to cross it."		
Teacher: "Like the vertical tangent X can never be 1 but I'm not saying that X can never be or Y can never be 3. We don't know that. Maybe, but we don't know. Okay."	References vertical and horizontal asymptotes	
Teacher: "It's just -the horizontal asymptote gives you the direction like gives you some boundaries tells you like where it is going."		
S4: "It is a suggestion of direction?"		
Teacher: "In this case yes, yea, but not always. I just wanted to – sometimes people are like it is like a police, like, do not run across the line. A horizontal asymptote is a little bit different. It – it's more about the shape of the graph. But in this case I don't think it is going to cross."	References vertical and horizontal asymptotes	

During the supported-didactic teaching condition, the types of student explanations were limited to providing values for quantitative expressions the teacher was prompting for the worked example she was guiding and displaying on the IWB. Thus, during the supported-didactic observation the instruction comprised predominately procedural content for calculus worked examples. Moreover, the didactic approach restricted the use of the IWB interactive features. Therefore, when the dialogue included connections and inferences about the worked example, the IWB could only be used for a visual reference rather than a visual display of conceptual knowledge. Under different conditions, an interactive instructional approach could be used to further support student conceptual understanding of graphs and asymptotes by manipulating a curve towards the asymptotes on the board or using a web-based simulation to illustrate the motion of a graph as it approaches the asymptotes.

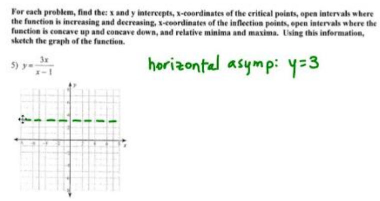
Interactive teaching condition. The lesson conducted under the interactive condition consisted of six examples presented by the teacher to the whole class. Of those six examples, one was discussed without using the IWB. Under the interactive condition, the presentation techniques used were the pen, overwrite, highlight, and hide or reveal. The hide or reveal feature was used once throughout the lesson. For this lesson, the worked example problems were copied from the student handout (Appendix E) that was electronically stored on the computer and pasted into the IWB presentation prior to the instruction. Figure 4-7 shows a sample of the IWB screen shot.

Figure 4-7. Teacher-Led Interactive Condition Screen Shot of IWB



Monica introduced a worked example to the class by asking a procedural question about horizontal asymptotes (see Figure 4-8).

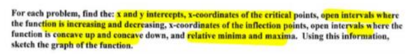
Figure 4-8. Teacher-Led Interactive teaching condition (Excerpt 1)

Talk	Board Usage	IWB Visual Display
Teacher: "So I believe last class, uh, we talked about – Before we left, we talked about the asymptotes. Yes? Okay. So even though we, they don't say asymptote but still, like, that's going to help us graph. So how do I find a horizontal asymptote?" **S1**: "Ratio…" **Teacher**: "Yeah. It's the ratio of the leading coefficients– If the degrees are the same, and are they the same?" **WC**: "Yes" **Teacher**: "Because both the numerator and the denominator are linear, right?"	Write procedure step with pen	
Teacher: "So what would be the horizontal asymptote again? Would we just say it's three, or what would we say? It was three, yeah, x equals three." **S1**: "y"	Draw horizontal asymptote with pen	
Teacher: "Sorry, y equals three."	Write solution with pen	

Patterns of talk emerged under the interactive teaching condition. First, during the second lesson, 60% of the questions asked by the teacher to the students focused on completing the procedural steps for the worked example solution. Second, while Monica wrote the procedure steps on the board, she completed students' sentences without allowing for student self-explanation of the example. The teacher's dialogue was a narration of the solution steps to the students providing little opportunity for class discussion about the worked example. Third, there were instances where Monica would use the highlight feature to identify the multiple parts of the problem that needed to be solved. She used this opportunity to provide students with advice for taking the AP Calculus Exam.

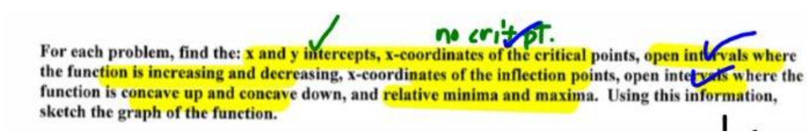
Monica stressed the importance of answering all parts of a multi-step problem to the students (see Figure 4-9).

Figure 4-9. Teacher-Led Interactive teaching condition (Excerpt 2)

Talk	Board Usage	
Teacher: "Uh, okay. So let's go through – So one thing that you want to do, anytime you have a problem type that has all this different stuff, you want to go through and, like, make sure that you have done all things on the list." **Teacher**: "Okay, so let's talk about – What do we have so far? X and Y intercepts, so what else do I need to know? We've got a lot to do. What else do we define? X coordinates and critical points, open intervals with the function increasing and decreasing, X coordinates of the inflection points, open intervals of the functions concave up and down, and relative min and max. That's a lot to do, right?"	Identifies problem steps with highlight pen	

Once Monica solved a problem step, she would use the overwrite feature on the list *for emphasis* highlighting the germane elements (see Figure 4-10) to the class and to denote that the part of the problem had been completed.

Figure 4-10. IWB screen shot of highlight feature used to denote problem steps

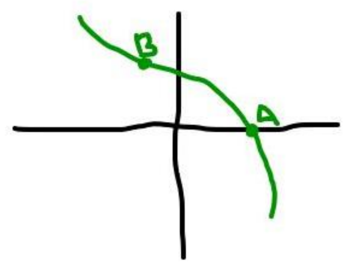


Whereas 68% of the questions asked by Ms. Stepps to the students focused on completing the procedural steps for the worked example solution, instances of conceptual dialogue occurred and warrant further discussion.

The problem-type of the examples covered the application and interpretation of derivatives about the Cartesian coordinate plane. To solve these problems, a conceptual understanding of the derivative and the generalizations of the function to any curve on the coordinate plane is required. In order to solve the problem-types presented in this lesson, further conceptual understandings of topics in calculus, geometry, and algebra are needed. The content of the second lesson steered the direction of class discussion towards conceptual dialogue and the researcher was able to capture the use of the IWB to support conceptual understanding. The following is an example of conceptual dialogue during the interactive teaching condition.

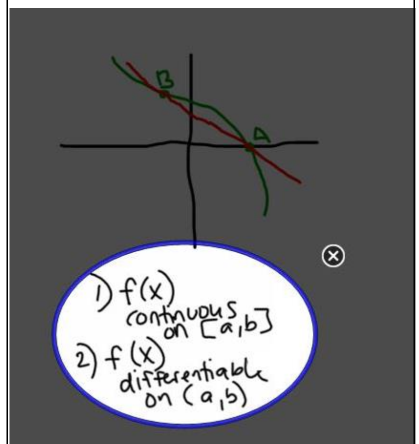
Monica reviewed the Mean Value Theorem with the students (see Figure 4-11) prior to beginning the solution step procedures for the given problem.

Figure 4-11. Teacher-Led Interactive Teaching Condition (Excerpt 3)

Talk	Board Usage	IWB Visual Display
Teacher: "Okay, this is what the Mean Value Theorem says, okay? You ready? What it says – Okay, so I'm not going to do this problem right this moment. We're just going to talk about the arrangements with Mean Value Theorem." **Teacher**: "If you have a continuous function, it has to be?" **Multiple students**: "Positive" **Teacher**: "Continuous…" **WC**: [Crosstalk – students calling out answers] **Teacher**: "Okay, okay. It has to be continuous on the close, differentiable on the open. Those are the two conditions, right? So it just means that – So here's, here's a function. Here's A. Here's B."	Draws graph with pen Writes conditions with pen Plots points on graph with pen	

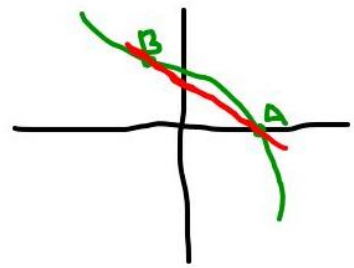
Monica used the IWB for a visual display of the example and continued her explanation about the conditions under which the Mean Value Theorem can be applied. When she drew the graph to support the conceptual understanding of the conditions, Monica continued to talk without allowing for student self-explanation of the example (see Figure 4-12).

Figure 4-12. Teacher-Led Interactive Teaching Condition (Excerpt 4)

Talk	Board Usage	IWB Visual Display
Teacher: “Okay. Continuous, so it has to be – Here are the conditions, and they will check for conditions. Continuous on the close, which means, like, has to be continuous end point to end point, okay?”	Writes conditions with pen	
Teacher: “And then it has to be differentiable on the open. So, uh, it for example could not be a vertical line.”	References graph	
S4: “There’s a sharp point turn at the right end of the graph?”		
Teacher: “It has to be end point to end point, so, like, uh, the absolute value function not, would not work at the sharp point.”		
S4: “What if it was past the (sharp point)?”		
Teacher: “Yes, unless it was – If the sharp point is in the interval, then you couldn’t do the mean value theorem. Okay? Does everybody – That kind of make sense? You’re kind of like ‘yeah sure, I got this.’ This is what the mean value term says. And by the way, these conditions are super-important.”		
Teacher: “It’s like – ok where is the magic pen?”		
Teacher: “It’s like, this”	Hide and reveal with ‘magic pen’	

Ms. Stepps used the ‘magic pen’ to hide and reveal the conditions she wanted her students to remember. The students commented how they liked the interactive feature. Ms. Stepps continued the conceptual explanation (see Figure 4-13).

Figure 4-13. Teacher-Led Interactive Teaching Condition (Excerpt 5)

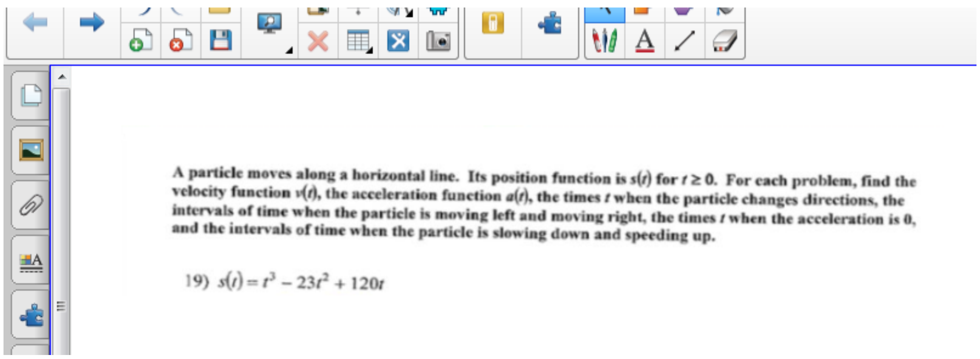
Talk	**Board Usage**	
Teacher: "Okay. So now that you know – Okay, all right. This is what the mean value theorem says, okay? Okay, if this point is A, what's the Y value of this X?"	Reference graph	
Teacher: "All right. the mean value theorem says that of the slope, the actual slope of this line, okay – Like if I drew a line from point A to point B, the slope of this red line is exactly equal to the derivative of this line at least one point. Okay."	Draw line with pen	
Teacher: "So the actual slope of the tangent line is equal to, uh – Like, the slope of this line is equal to the slope of the tangent line of this green line, this green curve for at least once in the interval"	Reference graph	
Teacher: "That's what the mean value theorem says. Does that make sense? So slope of red, non-calculus, equals derivative of green at least once in interval a and b."	Reference graph	

During this part of the example, Monica used the green color pen to illustrate the Figure 4-13. Interactive teaching condition – excerpt 5curve used for visual support about the Mean-Value Theorem conditions. Next, she used the red color pen to draw a line to represent the slope that is determined by applying the Mean-Value Theorem.

Under the interactive teaching condition, explanations were used to provide values for quantitative expressions the teacher was prompting for the worked example she was guiding and displaying on the IWB. During the second lesson, there was evidence of explanations that expanded generalized conditions or inferred consequences of action. The interactive approach permitted the use of more IWB features, such as overwrite and hide and reveal. Monica used the interactive features to direct student attention to problem steps and conceptual ideas. However, the teacher centered pedagogy limited student opportunities to engage in dialogue about the worked examples.

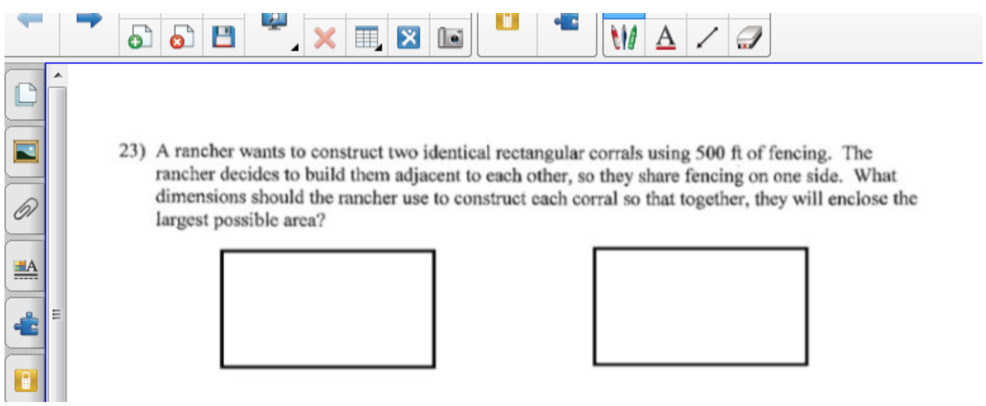
Enhanced interactive teaching condition. The enhanced interactive condition consisted of four examples presented by groups of two students to the whole class (see Figure 4-14). Ms. Stepps sat in a desk in the back of the room. Under the enhanced interactive condition, the presentation techniques used were the pen, overwrite, and highlight.

Figure 4-14 Student-Led Enhanced-Interactive Condition Screen Shot of IWB without Manipulative



Pictures and diagrams that could be manipulated by the student were included on two worked examples in the presentation (See Figures 4-15 and Figure 4-16).

Figure 4-15. Student led Enhanced-Interactive Condition Screen Shot of IWB with Manipulative

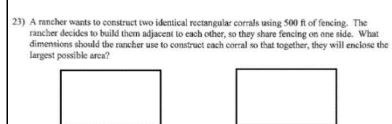
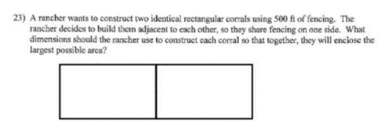


Each pair of students took turns using the board to present the worked example. The student pairs consisted of two sets of both males, one set of both female, and one set of mixed gender. The following discusses the four pairs of student presentations as it pertains to the research questions.

There were times where students had difficulty teaching with the IWB due to their unfamiliarity with the technology. The following scenario illustrates the difficulties the students were having and how they coped with it.

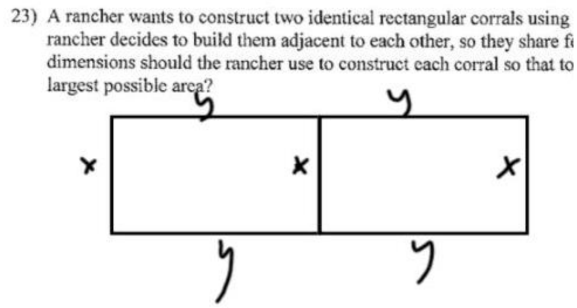
John navigated to the assigned worked example and read the problem out loud to the class. He referenced the two rectangles placed on the screen that serve as visual supports for the worked example.

Figure 4-16 Student-Led Enhanced-Interactive Teaching Condition (Excerpt 1)

Talk	**Board Usage**	**IWB Visual Display**
John: "So we have to, um, build two identical rectangular corrals with 500 total feet of fencing"	Reference problem	*Before Manipulation*
John: "so this picture is kind of annoying because they are actually apart and not adjacent in this picture."	Reference visual support	
Teacher: "You can move them together"		
John: "Can we?"		
Jane: "You can do it."		*After Manipulation*
Teacher: "Yeah, move them wherever you want. Now touch it."		
John: "Oh, I don't like this." [Laughter]	Reference visual support	
Teacher: "Yeah, no move it."		
Jane: "That is very, very valuable"	Manipulate visual support	
John: "Okay, this is the correct picture."		

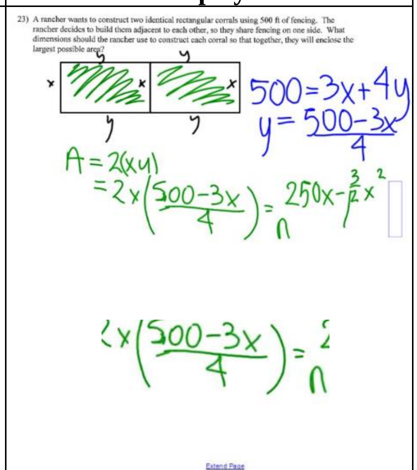
John suggested a solution strategy and labeled the diagram. When he finished labeling the diagram, he gave Jane the pen to continue writing the worked example (see Figure 4-17).

Figure 4-17. Student labeled diagram



Jane continued to write out the procedural steps on the IWB while John explained the worked example. Jane ran out of room on the screen to write the next procedure step (see Figure 4-18). Ms. Stepps suggested scrolling down.

Figure 4-18. Student-Led Enhanced-Interactive Teaching Condition (Excerpt 2)

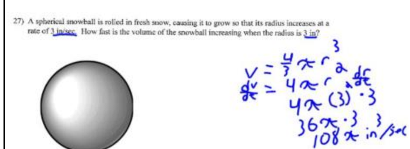
Talk	**Board Usage**	**IWB Visual Display**
Jane: "Can we, like add a new page?"		
[Laughter]		
Teacher: "Scroll down"	Manipulate page	
Jane: "I don't like this"		
[Laughter]		
Ralph: "Hey! There is 'extend page' at the bottom."	Reference board	
John: "Let's do that thing."		
[Laughter]		
Jane: "Oh"	Manipulate page	

When Jane and John were using the IWB, they both indicated they did not like the technology. In context, these statement were said jokingly and reflected students' unfamiliarity with the technology. As Jane and John continued to use the technology, they became more familiar with its features.

Patterns of talk emerged under the enhanced interactive teaching condition. First, during the student led instruction, procedural talk comprised 64 % of the dialogue. Second, while the students wrote the procedure steps on the board, they would provide explanations that refined or inferred conditions about the worked example. Third, there were instances when students struggled with conceptual understanding about the worked example. When these issues occurred, Ms. Stepps would interject and provide explanation from the back of the room.

In the example shown, Caleb and Jonah presented a problem that involved increasing the volume of a sphere given rate of three inches per second (see Figure 4-19). Caleb explained the worked example while he wrote the procedure steps on the board.

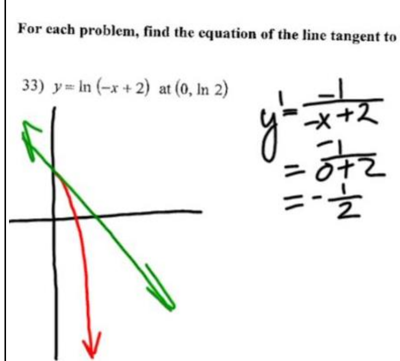
Figure 4-19. Enhanced-Interactive Teaching Condition (Excerpt 3)

Talk	**Board Usage**	**IWB Visual Display**
Caleb: "So, um, it starts out by giving you the radius increases at a rate of 3 inches per second so what I do on this is I just write that out underneath to keep everything organized."	Annotate with blue pen	
Caleb: "And then what you're trying to find is the volume or - yeah, the rate that the volume is changing when the radius is 3 inches."		
Caleb: "So, um, what, ah, I do to start this is since you're trying to find the volume you need to setup an equation solving for the volume and in this case, for a sphere it's, um, V equals 4/3 pi, radius Q."	Write procedure steps with blue pen	
Caleb: "And um, then because you're trying to find the rate that the volume is changing, you take the derivative of it."		
Caleb: "so you're going to take the derivative of those and you'll have DV over DT equal to four pi, times R squared, and then times R prime, which is DR over DT."		

Caleb continued with the worked example explanation and finished writing the procedures on the board. The conceptual dialogue did not include whole class discussion about the work example, but rather was explained by Caleb to the whole class while he wrote the procedure steps on the board. In addition to procedure steps, the IWB was used to direct attention to important information in the worked example problem.

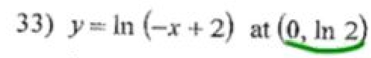
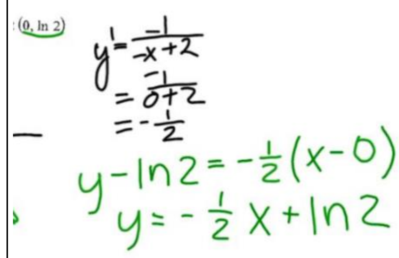
Ms. Stepps asked the whole class if there were any questions about the related rate problem. Nobody responded and the next pair of students went to the board. Sue and Lydia presented a problem that involved finding the equation of a line tangent to a curve at a given point. In this case, there were no images or diagrams on the screen for the students to manipulate. Sue began the presentation by explaining the desired solution for the problem. She sketched an estimation of the curve and the tangent line on the coordinate plane. Sue used different colors to represent each graph. She explained the procedure steps as she was writing on the IWB (See Figure 4-20). When Sue justified the procedure steps by explaining the relationship between natural logs and the derivative, she conveyed a conceptual idea.

Figure 4-20 Student-Led Enhanced-Interactive Teaching Condition (Excerpt 4)

Talk	**Board Usage**	**IWB Visual Display**
Sue: "Okay, so it's asking for each problem finding the equation of the line tangent to the function at the given point." **Sue**: "So, basically, we have Y equals an natural log of negative X plus 2, on a graph that kind of like - looks like this," **Sue**: "and the line we're looking for is the line at zero, and natural log of 2, which is like - kind of like that." **Sue**: "So, um, to start finding that we need to find the derivative and the derivative is negative 1 over negative X plus 2, because for natural log, the derivative is D over U." **Sue**: "and then, when we plug in zero for X we get negative 1 over zero plus 2, which is also negative 1 so that is your slope."	Reference problem Draw coordinate plane and red curve Draw green line Write procedure steps on board with black pen.	

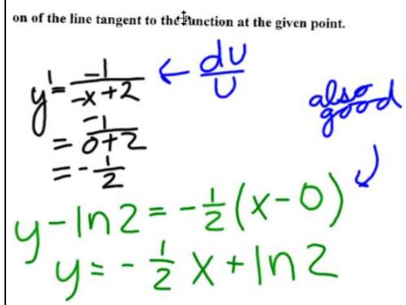
When Sue finished finding the slope, she handed the pen to Lydia who continued the problem (see Figure 4-21).

Figure 4-21 Student-Led Enhanced-Interactive Teaching Condition (Excerpt 5)

Talk	Board Usage	IWB Visual Display
Lydia: "Okay, so now you have the slope and you also have this point." **Lydia**: "So now it's really easy, you just put it in point slope form.	Overwrite point with pen	
Lydia: "So, Y minus natural log of 2, equals negative ½, X minus zero, and then you just rearrange it and you get Y equals 1 ½ X plus the natural log of 2	Write expression	

After Sue and Lydia finished the worked example, Ms. Stepps posed a conceptual question to the class. Lydia noted the important concepts on the board during the teacher's explanation using a different color (see Figure 4-22).

Figure 4-22. Student-Led Enhanced-Interactive Teaching Condition (Excerpt 6)

Talk	**Board Usage**	**IWB Visual Display**
Teacher: "Okay really quickly notice what that derivative is. It's a negative 1; do you guys see why it's negative 1?"		
Teacher: "Okay, sometimes we have a habit of thinking that the derivative of natural log - just X that out for me. Um, we get into the habit of thinking that the derivative natural log is 1 over U."		
Teacher: "no - no - no - what is it kids? D over U"		
Teacher: "D over U, that's an easy place where we can make a mistake and just wanted to point that out."	Annotate screen with pen	
Teacher: "And also, on the AP exam, do you have to solve for Y?"		
Multiple Students: "No."		
Teacher: "If it's an FRQ (Free Response Question), you can just leave it Y minus natural log of 2, leave it in that form, you don't have to solve for Y. I just wanted to point that out. Okay? You guys have any questions?"	Annotate screen with pen	

The example presented by Jamel and Frank required students to solve for acceleration and velocity using calculus. During the presentation, Brittany had a question regarding a procedure step based on a conceptual idea. When Jamel and Frank explained the conditions under which the procedure could be completed, they did not use the IWB (See Figure 4-23).

Figure 4-23 Student-Led Enhanced-Interactive Teaching Condition (Excerpt 7)

Talk	**Board Usage**
Brittany: "Um, to find if it's speeding up and slowing down do you have to have velocity function with it or just be like?" **Jamel**: "You have to have both acceleration and velocity just for the signs; the numbers themselves don't matter, but if the signs are the same, it's speeding up and if they're different then slowing down." **Frank**: "Because you're all looking for intervals not actual bodies of time." **Brittany**: "Okay, so where they're both negative, you're saying that's when it's speeding up?" **Sue**: "and then, when we plug in zero for X we get negative 1 over zero plus 2, which is also negative 1 so that is your slope." **Frank**: "Because the particle is moving in a negative velocity, and it's accelerating with a negative acceleration so both direction and same direction it accelerates." **Jamel**: "You have to kind of think of it as when you multiply a positive and a negative, you still get a negative so like - that's how I was taught."	n/a

At this point, Ms. Stepps interjected to further refine the conceptual understanding of acceleration and velocity. She called for the students up front to simulate the actions she provided in her explanation (See Figure 4-24).

Figure 4-24. Teacher Intervention of Student-Led Enhanced-Interactive Teaching condition (Excerpt 8).

Talk	**Board Usage**
Teacher: "Okay, so Frank, move backwards like real slow. Now, Jamel just give him a push backwards, like he's going to push him." **Lincoln**: "Keep moving, get velocity this way." **Teacher**: "Okay, so Frank, move backwards like real slow. Now, Jamel just give him a push backwards, like he's going to push him." **Brittany**: "Yeah." **Teacher**: "So Frank is moving in a negative direction and if a force is applied in that same direction, it's going to make him speed up." **Brittany**: "Okay."	n/a

Under the enhanced interactive teaching condition, explanations were used to provide values for quantitative expressions for the worked example being presented by the students on the IWB. During the third lesson, there was evidence of student explanations used to infer or expand on conceptual knowledge about the worked example. The enhanced interactive approach permitted the use of more IWB features, such as images and objects to manipulate. The students used the interactive features to direct attention to the problem steps and conceptual ideas. Even though the enhanced-interactive teaching condition was student-led, the teacher-centric pedagogical method employed by the students limited opportunities for whole class dialogue about the worked examples.

Summary

In the Findings Part I section, the results of the district survey indicated Algebra 1 teachers used few if any interactivity features of the IWB, with use only as a non-interactive whiteboard. A majority of the teachers indicated a need for professional development training with the IWB. The case study teacher was an experienced math teacher who reported she was comfortable with technologies to support mathematics instruction. She had also been selected for national recognition to implement 21st Century Next Generation Learning principles. Ms. Stepps indicated being aware of the potential benefits of interactive pedagogy when using the IWB. However, the only training she had received previously covered how to use the features of the IWB rather than strategies and methods of interactive pedagogy. Previous student use of the IWB in Ms. Stepps' classroom displayed assigned homework problems to the class. The students would explain the solution steps to this class as they presented the worked example. This activity occurred routinely once or twice a week. However, there was little evidence of student use of the interactive features of the IWB for instruction prior to this study.

In Findings Part II, audio and video transcripts of the teacher-led and student-led worked example instruction provided data to answer the study's research questions. Under both the teacher-led and student-led instruction, the teacher-centric lecture based pedagogy limited collaborative whole class dialogue. During the worked example instruction, the content of talk most prevalent in the three lessons consisted of the procedure steps taken for problem solution. However, dialogue connecting conceptual knowledge to procedural steps about the worked example was evident throughout the three lessons.

During both teacher-led worked example presentations, the student self-explanations were limited to providing values for quantitative expressions the teacher was prompting for the worked example she was guiding and displaying on the IWB. Conceptual explanations that expanded conditions or inferred consequences were provided largely by the teacher under the teacher-led instructional approach.

During the student-led condition, there was evidence of self-explanations that provided values for quantitative expressions for the worked example. In addition, student self-explanations defined parameters under which a procedural step could be taken and expanded conceptual conditions of the worked example. There was evidence of student discourse used to make meaning and develop understanding of the conceptual knowledge about the worked example.

The pedagogical methods used to present the worked example instruction guided the interactions among the presenter(s), the whole class, and the IWB. During the teacher led instruction, the IWB served as a visual display for the procedure steps using the pen feature. There were instances where the teacher used color to delineate the order of the procedure steps. Under the supported-didactic and interactive conditions, the teacher referenced the worked example on the screen to support conceptual understanding about the worked example. The teacher used interactive features, such as highlight and hide and reveal, direct learner attention to a problem steps and demonstrate test-taking strategies for the AP Calculus II Exam.

Even without prior training with the IWB, the students were able to learn how to use the IWB features easily. If a student presenter had technical difficulties, suggestions for resolution were offered by both the teacher and the students. Similar to the teacher, the students used the IWB to display procedure steps using the pen feature. Interactive features, such as overwrite and manipulatives, were used to direct attention to the problem steps and conceptual ideas. In some cases, color was used to delineate the order of the procedure steps. Additionally, there were instances where color was used to display connections and inferences related to the worked example providing a heuristic view of conceptual knowledge.

In Chapter Five that follows, the researcher discusses the findings from this embedded, single case study and makes connections across conceptual framework and the results of this study to further inform the research questions through discussion and interpretation of the findings. Chapter Five also includes implications and suggestions for further research are also included.

Chapter 5

Discussion, Implications, and Future Research

Introduction

This dissertation study investigated the use of the IWB in a high school calculus classroom during worked example instruction. The focus was to examine how the IWB mediated dialogic interaction and student self-explanation, as well as two interaction formats shown in the literature to develop conceptual understanding during worked example instruction. Overall, the findings noted in Chapter Four illustrated an impoverished implementation of the IWB interactive tools and resources to support dialogic interaction and students' self-explanations – two critical components of effective worked example instruction. In this chapter I discuss these findings and draw implications about future improvements related to the implementation of the IWB, or any interactive display mediation tools, that may support dialogic interaction and self-explanations of concepts in high school classrooms that use modeling and worked example instructional strategies for mathematics instruction.

Discussion: Rethinking Levels and Purposes of Technology Professional Development for Teachers

Professional development requires pedagogical focus

When schools and districts implement instructional technology, such as the IWB, they often focus on the most immediate needs such as purchasing the required hardware and ensuring the technology is installed properly and functions as it is intended. However, interactive display technologies, like any instructional technology are not transformative on their own, but require teachers to have knowledge of how the interactivity can be used to improve student learning. In this study, the district implementation of the IWBs failed to address the pedagogical changes needed to use an interactive display technology for instruction effectively. In this case study, the paradigm of instruction needed to prepare students for college and 21st century careers was not the paradigm of instruction used in practice. In other words, professional development can no longer just be about exposing teachers to a concept or providing basic knowledge about a teaching methodology. Instead, professional development in an era of accountability requires a change in teacher practice that leads to increases in student learning.

Successful implementation of interactive display technologies requires a balance between both the school's support structure and the competencies of its teachers. During the initial stages of interactive display implementation, it is important for teachers to be trained on the technical aspects and features of the technology. Simply put, the teachers need to know how the technology works. However, as teachers become more technically competent, the shift towards more training opportunities in regards to interactive display implementation and pedagogical methods is necessary.

Using IWB Displays and Dialogic Interaction to Inform the Design of Professional Development

The findings of this study provide beneficial design factors that can be considered when designing professional development for interactive display technologies so that teachers are able to understand and apply interactive pedagogy to improve student learning from worked example instruction.

Recommendation #1: Focus on student outcomes by using the interactive display and capture of student talk to demonstrate conceptual and procedure understanding.

The method of capturing dialogue integrated with the screen shots as demonstrations of students' self-explanations extends research in dialogic learning, worked examples, and interactive displays. But it is also a template for implementing professional development that focuses on the pedagogical outcomes that can be demonstrated and measured in a classroom.

Extrapolating from the student self-explanation data, implications were revealed that suggest ways to improve teacher professional development using dialogic data as the basis for teachers to examine and deconstruct pedagogical practices with interactive display technologies. The research suggests the following considerations for the design of professional development programs focused on interactive display technology.

Recommendation #2: Use dwindling professional development time primarily for focusing on pedagogy.

Overwhelmingly, the literature concurs that the effective use of the features of the IWB directly relate to the proficiency in which the teacher uses the tool for instructional presentation (Miller, et al., 2004; Higgins, et al., 2007). Moss et al., (2007) proposed that when teachers used an IWB for at least two years new patterns of teaching practice or new developments of established patterns were observable in the data, and the IWB became embedded in their pedagogy as a mediating artifact that increased interactivity within the classroom. Therefore, the duration of professional development must be significant and ongoing to allow for teachers to learn new strategies and grapple with the implementation problem.

Simply increasing the amount of time teachers spend in professional development is not enough. The time has to be spent wisely. To accomplish this, the professional development should address the specific challenges of learning a new technology and changing classroom practice. Of course, technical training should begin with the basic operations and features of the interactive display technology and continue throughout the duration of the professional development. However, teacher training on the advanced interactive features of the display technology should progress based on the dialogic data gathered during worked example instruction allowing the teacher's technical knowledge to grow as their understanding of interactive pedagogy develops. Scaffolding teacher training of the advanced interactive features with dialogic data and screen shot displays allows teachers to engage through varied approaches so they participate actively in making sense of the new practices.

Recommendation #3: Focus specifically on student data generated by the interactive display technology that demonstrates conceptual dialogue and understanding.

The methods of data collection and reporting in this study can be used to inform the teacher how the interactive display technology supports conceptual dialogue about the worked example. Teachers can collect similar data and use the information to examine and deconstruct pedagogical practices with interactive display technologies. Not only could teachers use this data to solve relevant problems with their teaching practices, but also see the rich demonstrations of students' understanding and use that information as a formative assessment. Therefore, professional development training must address how to use the evidence to gain insight on student understanding and further, how to make informed decisions about teaching practices to improve student learning.

Recommendation #4: Use interactive display technologies to explicitly demonstrate students' 21st century skills.

Over the past decade, numerous research and reports have emerged to identify the skills needed for success in the 21st century world. While there are some differences in how the skills are categorized or labeled, there is a consistent presence of the importance of technology integration into the academic curriculum. When used effectively, the IWB or any interactive display technology can support 21st century core competencies like collaboration and problem-solving. In fact, the first IWBs were used in offices for sharing and presenting ideas within business groups. With today's internet technologies, interactive business collaboration occurs across cities, states, and countries. Therefore, it is important for teachers to embed opportunities within the curriculum for students to learn how to use interactive technology in collaborative settings. It is no longer sufficient for students to have less access to technological tools than the teacher. However, collaborative opportunities, stimulating discussion through problem-solving, were not fully exploited by the teacher. As a result, students in the case study classroom had very little experience using the IWB for anything other than a white board to display worked examples on the screen.

In the present investigation, despite the students having very little experience using the interactive features of the IWB, there was evidence of collaborative interactions during the student-led instruction. The theoretical framework for this research is based on the view of learning as a social and cultural mediated process (Vygotsky, 1976). Specifically, this study examined how the IWB was used as a presentation tool to create conditions for learning about worked examples within the theoretical framework provided by socio-constructivism. During the student-led instruction, the experts (the student presenters) guide the class through a series of scaffolds *mediated* (emphasis added) by a tool (the IWB) to facilitate schema construction about the conceptual ideas of the problem type. Extrapolating the pairs of student presenters as a collaborative 'group,' students negotiated board usage, displayed procedural steps, and mutually scaffolded conceptual ideas. Students should be scaffolded to explicitly understand how their use of interactive display technologies is a tool for promoting their 21st century skills.

Recommendation #5: Outcomes for professional development need to explicitly task the teacher as a role model for students to fully engage with interactive display technology for dialogic understanding.

Teacher professional development needs to focus on teachers as role models for students not just instructor who knows how to use the IWB. In his seminal article, *Digital Natives Digital Immigrants Part 1*, Prensky (2001) introduces two new terms he defined as "digital natives" and "digital immigrants." According to his explanation digital natives are the children who have grown up in a world surrounded by and using computers, cell phones, and other digital technologies. Consequently, they have the skills for digital fluency. One could suppose that students' prior experience with touchscreen interactive technologies (e.g., smartphones, iPads, etc.), provided baseline skills for using the IWB. During the student-led instruction, the students easily adapted to the functionality and features of the interactive technology used to display the worked example presentations.

Prensky's article was written as an opinion piece loosely based on neuroscience and social psychology. For that reason, the article has been criticized for lack of empirical data to support Prensky's claims that there are generational differences in the way that people learn technology. Bennett (2008) stated, "rather than being empirically and theoretically informed, the debate can be likened to an academic form of a 'moral panic.'" (p. 776). As a result of the criticism, Prensky discarded the digital native metaphor for a more heuristic view to understand the various ways individual engage with digital technology. The premise behind Prensky's dichotomous digital landscape has important implications for teacher understanding of how students learn when using technology. Subsequently, considerations must be given to the pedagogical practice used to facilitate such learning when using technology. The students in the case study classroom clearly were comfortable with the function and features of the IWB regardless of previous experience using the technology. However, interactive activities and collaborative opportunities were not fully exploited by the teacher during daily practice. As a result, students in the case study classroom only had knowledge of the use of the IWB as a white board to display worked examples.

Therefore, the design of professional development should support teacher growth and understanding of both interactive and dialogic teaching strategies through modeling student cognitive engagement. Specifically, the teacher's use of the interactive display technology during training results in student led episodes in their own classrooms. In essence, teacher training would not be just learning the features, but how to pedagogically model 21st century learning using the interactive display technology for the students.

Theoretical Implications for Teacher Professional Development Practice

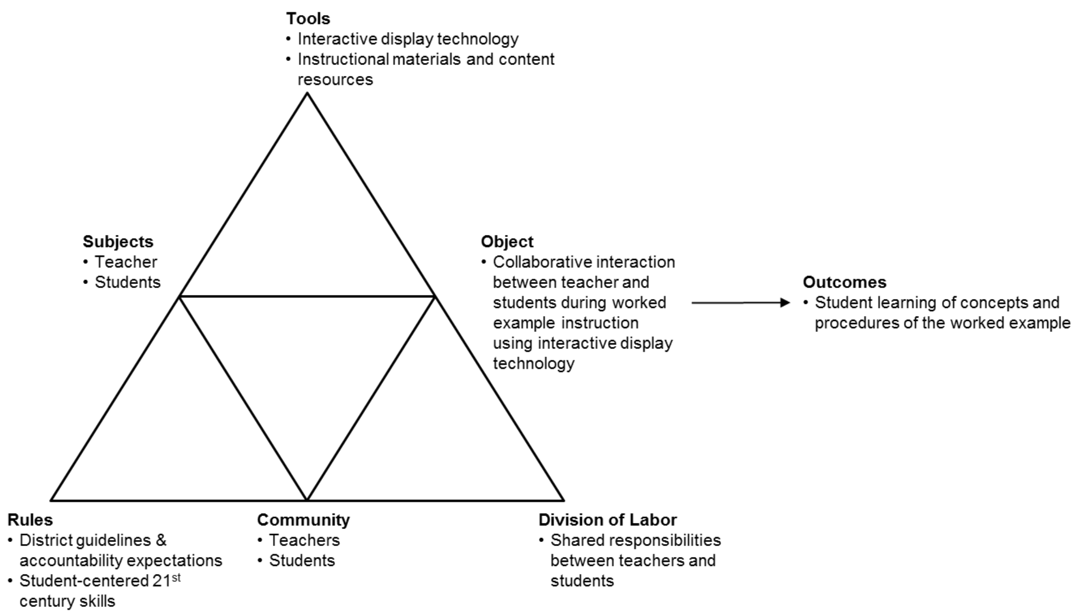
Although this study was focused on IWBs, the same research model could possibly be beneficial in other areas of interactive technology integration in education. Assuming that many districts will have similar problems with volume of training required versus the limited resources to provide training, a theoretical model would have to be designed to provide training that ties the use of technology to standard and avoids time consuming and ineffective methods of passive professional development for providing rich, tool-mediated dialogic instruction, well documented as a requirement for robust learning of both procedural and conceptual content.

For the purpose of this study, Activity theory (AT) provided a framework to contextualize the use of the IWB as an instructional tool used for worked example presentations. This framework was especially useful for examining the IWB as a mediating artifact facilitating interaction between members of the community (see Figure 2-4). A theoretical implication of this research study is a recommendation for a similar approach using AT to guide the design of professional development for interactive display technologies as shown in Figure 5-1 below.

In Figure 5-1, consider the activity system formed by the teacher, students, and the IWB in the case-study classroom. The IWB literature suggests the technology can be used to facilitate discussion between the students and teacher and serves as a mediating artifact that encourages dialogic learning (Murcia & Sheffield, 2010). The desired outcome of the activity system is the student learning of structural features and solution procedures of the worked example problem types. In essence, the IWB would serve as a platform to mediate understanding about the worked example. In order to mediate understanding, the teacher and students must share responsibility for dialogic interaction. The quality of interactions in the case study classroom was found to be dependent on the opportunities created for reflection and on the quality of the questions posed. However, opportunities to develop a more interactive approach, stimulating discussion through open and probing questioning, were not fully exploited by the teacher. Effectively, the IWB was used to display and transmit information in a routine matter with limited opportunities for interaction and discussion. The teacher-centric instruction prohibited the affordances of the IWB to serve as a joint reference for dialogic interaction. In this case, the IWB was used simply as a white board to present the worked examples and any interactivity in the classroom was not directly attributable to the use of the IWB but rather a function of the pedagogy.

The division of labor construct in the activity system references which members of the community engage in which types of actions using which tools. In a teacher led classroom, the teacher is the heart of the activity system where the pace, sequence, and assessment process is controlled by the teacher. Student centered, interactive pedagogy requires the distribution of power and control to include the student as an active community member throughout the teaching and learning event. The pedagogical shift from teacher centered to student interactive requires teachers to use interactive display technology as a mediating artifact for shared understanding. As testing and other structures guide classroom practice, professional development opportunities in technology integration tend to focus on the 'tool' construct of the activity system as it relates to the outcomes. The outcomes are related directly to student performance on accountability exams. As a result, the division of labor, a critical component of sharing responsibilities, is overlooked as an essential component to teacher training.

Figure 5-1. Activity theory system for interactive display technology professional development



The design of professional development for interactive display technology should communicate to the teachers the importance of shared responsibilities between members of the community and emphasize the significance of active participation by the student during the instruction. Using the tools and resources that technology offers, students can express, evaluate and revise their ideas interactively while they visualize problem solution. Multimedia simulations with interactive technologies offer dynamic representations of conceptual ideas and aid in the student visualization of abstract knowledge in mathematics. However, in order to form this new mindset of teaching through technology, a vital shift in the roles of teacher and student must emerge. In this configuration, the teacher acts as a learning catalyst, orchestrating and facilitating activities that depend on understanding of the mathematical concepts. As teachers spend less time creating presentations and more time crafting powerful learning activities, they will find that material is covered with more depth and retention.

Areas of Future Research

Using IWB or interactive display technologies in other content areas

This study examined the use of an IWB for worked example instruction in an AP Calculus II class. The structure of the research design supports the use of interactive technologies in different content areas such as English, social studies, and foreign language as well as cross-curricular projects. In addition, this study examined the use of the IWB during worked example presentations in an upper-level secondary classroom. Additional research is needed in how the use of interactive technologies can be used to support and assess student understanding of knowledge and skills in additional content areas with students at different grade levels.

Professional Development for Teachers: Interactive Pedagogy

The degree of success teachers have in implementing interactive technologies depends in part on their understanding of the relationship among content, pedagogy, and technology. Support for the integration of the technology and interactive pedagogical strategies go well beyond the initial training on the technical skills. One way to build on this study would be to implement a professional development program for teacher participants prior to collecting observational data. As a result of the trainings, teachers would have a better understanding of the technical features and pedagogical affordances of the IWB. By taking a deliberative approach to professional development on interactive pedagogy, better data on the effect of the IWB features could be obtained.

Conclusion

This study was designed to explore the relationship between classroom discourse and interactive pedagogies when using the IWB for worked example instruction. This case study was guided by qualitative content analysis spiral developed by Schilling (2006) in order to examine the range and differences of exchanges and interaction that occur between the teacher, the students, and the IWB. The findings from this study could be used to enhance the implementation of interactive display technology integration in the K–12 environment. The depth of the study was limited to the participant that volunteered to participate in the study. The study produced data that could inform a 'next generation' of professional development training and recommendations for the integration of interactive display technologies in the classroom that would support dialogic learning and enhanced student self-explanations for worked example instruction in classroom mathematics content.

Appendix A
Student Worksheets

Calculus

Name________________________ ID: 1

Applications of Derivatives

Date________________ Period____

For each problem, find the average rate of change of the function over the given interval.

1) $y = -x^2 - 2x + 1$; $[-4, -1]$

2) $y = x^2 - 2x - 1$; $[0, 3]$

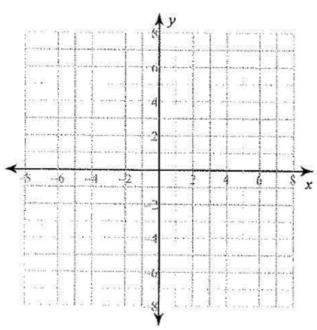
For each problem, find all points of absolute minima and maxima on the given closed interval.

3) $y = x^2 - 6x + 4$; $[4, 6]$

4) $y = -x^2 - 6x - 5$; $[-3, -1]$

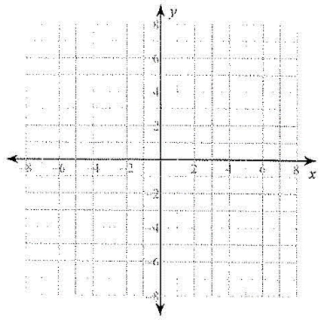
For each problem, find the: x and y intercepts, x-coordinates of the critical points, open intervals where the function is increasing and decreasing, x-coordinates of the inflection points, open intervals where the function is concave up and concave down, and relative minima and maxima. Using this information, sketch the graph of the function.

5) $y = \dfrac{3x}{x - 1}$



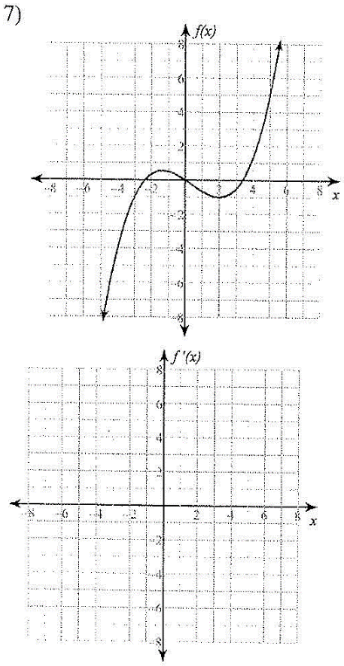
-1-

6) $y = -2x^3 + 2x^2 + 2x$

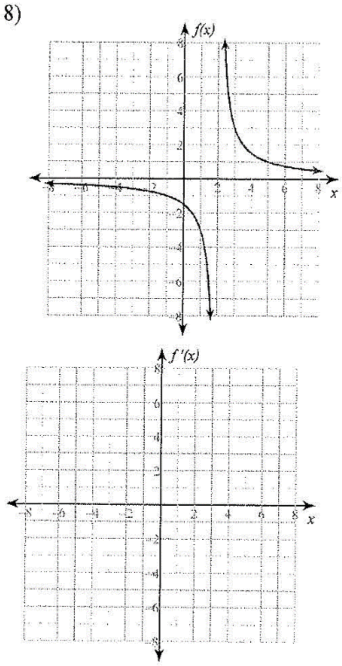


Given the graph of $f(x)$, sketch an approximate graph of $f'(x)$.

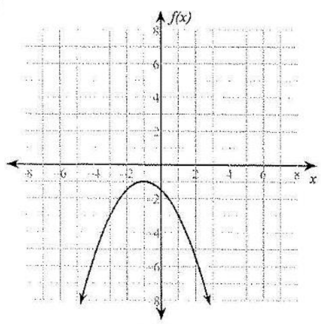
7)

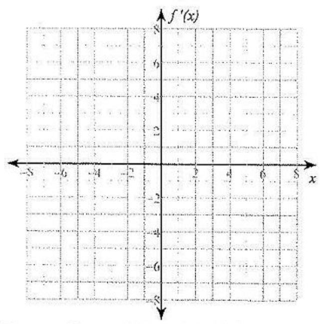


8)

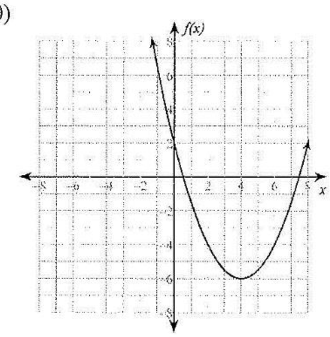


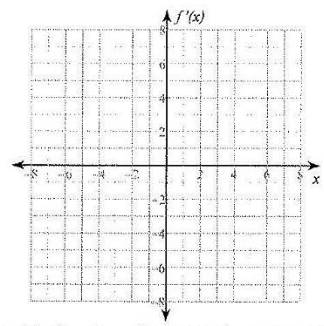
9)





10)





For each problem, find the x-coordinates of all points of inflection, find all discontinuities, and find the open intervals where the function is concave up and concave down.

11) $y = -x^4 - 2x^3 + x^2$

12) $y = \dfrac{x^2}{3x - 6}$

13) $y = \dfrac{x^2}{2} + x + \dfrac{3}{2}$

For each problem, find the open intervals where the function is increasing and decreasing.

14) $y = -x^3 + 4x^2 - 3$

15) $y = \frac{2x}{x - 2}$

16) $y = \sin(2x)$; $[-\pi, \pi]$

For each problem, find the values of *c* that satisfy the Mean Value Theorem.

17) $y = \frac{x^2}{2} + 3x - \frac{1}{2}$; $[-6, -4]$

18) $y = -2x^2 + 16x - 31$; $[3, 5]$

A particle moves along a horizontal line. Its position function is $s(t)$ for $t \geq 0$. For each problem, find the velocity function $v(t)$, the acceleration function $a(t)$, the times t when the particle changes directions, the intervals of time when the particle is moving left and moving right, the times t when the acceleration is 0, and the intervals of time when the particle is slowing down and speeding up.

19) $s(t) = t^3 - 23t^2 + 120t$

20) $s(t) = -t^2 + 14t - 48$

Solve each optimization problem.

21) A company has started selling a new type of smartphone at the price of $\$160 - 0.1x$ where x is the number of smartphones manufactured per day. The parts for each smartphone cost \$60 and the labor and overhead for running the plant cost \$5000 per day. How many smartphones should the company manufacture and sell per day to maximize profit?

22) A farmer wants to construct a rectangular pigpen using 100 ft of fencing. The pen will be built next to an existing stone wall, so only three sides of fencing need to be constructed to enclose the pen. What dimensions should the farmer use to construct the pen with the largest possible area?

23) A rancher wants to construct two identical rectangular corrals using 500 ft of fencing. The rancher decides to build them adjacent to each other, so they share fencing on one side. What dimensions should the rancher use to construct each corral so that together, they will enclose the largest possible area?

24) A cryptography expert is deciphering a computer code. To do this, the expert needs to minimize the product of a positive rational number and a negative rational number, given that the positive number is exactly 6 greater than the negative number. What final product is the expert looking for?

Solve each related rate problem.

25) A hypothetical cube grows so that the length of its sides are increasing at a rate of 2 m/min. How fast is the volume of the cube increasing when the sides are 4 m each?

26) Water leaking onto a floor forms a circular pool. The radius of the pool increases at a rate of 4 cm/min. How fast is the area of the pool increasing when the radius is 6 cm?

27) A spherical snowball is rolled in fresh snow, causing it to grow so that its radius increases at a rate of 3 in/sec. How fast is the volume of the snowball increasing when the radius is 3 in?

28) A conical paper cup is 10 cm tall with a radius of 30 cm. The cup is being filled with water so that the water level rises at a rate of 4 cm/sec. At what rate is water being poured into the cup when the water level is 7 cm?

For each problem, find all points of relative minima and maxima.

29) $y = \frac{x^2}{2x - 2}$

30) $y = x^4 - 2x^2 - 1$

For each problem, find the values of c that satisfy Rolle's Theorem.

31) $y = 2x^2 - 8x + 8;\ [1, 3]$

32) $y = -x^2 + 4x + 1;\ [1, 3]$

For each problem, find the equation of the line tangent to the function at the given point.

33) $y = \ln(-x + 2)$ at $(0, \ln 2)$

34) $y = (x + 1)^{\frac{1}{3}}$ at $(-2, -1)$

35) $y = \frac{x^2}{2} + 3x + \frac{11}{2}$ at $\left(-2, \frac{3}{2}\right)$

36) $y = (2x + 2)^{\frac{1}{3}}$ at $(3, 2)$

For each problem, find the equation of the line normal to the function at the given point.

37) $y = -\ln(x + 1)$ at $(2, -\ln 3)$

38) $y = \frac{1}{x + 3}$ at $\left(1, \frac{1}{4}\right)$

39) $y = -x^2 + 2x - 1$ at $(1, 0)$

40) $y = (-x + 2)^{\frac{1}{2}}$ at $(1, 1)$

Appendix B
District Teacher Survey

MathTeachersIWB

To Potential Participant:

You are being invited to take part in a research study to determine if and how the Interactive Whiteboard (IWB) can support student learning when used to present worked examples instruction in high school mathematics courses. You are being invited to take part in this research study because you currently teach mathematics in Fayette County public schools. If you volunteer to take part in this survey, you will be one of about 95 people to do so. Although you will not get personal benefit from taking part in this research study, your responses may help us understand more about how the IWB is being used to present mathematics instruction throughout the Fayette County school district. We hope to receive completed questionnaires from about 95 people, so your answers are important to us. Of course, you have a choice about whether or not to complete the survey/questionnaire, but if you do participate, you are free to skip any questions or discontinue at any time.

The results of the surveys will aid in the selection of a single-case study classroom. During the case-study data collection, audio and video recordings will be used to obtain whole-class dialogue and capture the interactivity between the teacher, students, and the IWB technology. The survey/questionnaire will take about 15-20 minutes to complete. There are no known risks to participating in this study. Your response to the survey will be kept confidential to the extent allowed by law. When we write about the study you will not be identified. The researcher will invite teachers to participate in a single-case study by requesting their names. The survey only requests teacher name to invite them to provide additional information, based on the aggregated responses of the group. Please be aware, while we make every effort to safeguard your data once received from the online survey/data gathering company (Qualtrics), given the nature of online surveys, as with anything involving the Internet, we can never guarantee the confidentiality of the data while still on the survey/data gathering company's servers, or while enroute to either them or us. It is also possible the raw data collected for research purposes may be used for marketing or reporting purposes by the survey/data gathering company after the research is concluded, depending on the company's Terms of Service and Privacy policies.

If you have questions about the study, please feel free to ask; my contact information is given below. If you have complaints, suggestions, or questions about your rights as a research volunteer, contact the staff in the University of Kentucky Office of Research Integrity at 859-257-9428 or toll-free at 1-866-400-9428.Thank you in advance for your assistance with this important project. To ensure your responses/opinions will be included, please complete the online survey by October 31, 2014

Sincerely,
Ellen C. Bloomfield
Department of Curriculum & Instruction, University of Kentucky
PHONE: 502-370-6324
E-MAIL: ebloomfield@midway.edu
Thank you for participating in this research.

Q1. Welcome to the Interactive Whiteboard Use Survey for Algebra Teachers. If you agree please proceed to the survey questions. By completing this survey, you are confirming you are over 18 and that you agree to participate in this study.

- ❍ Agree (1)
- ❍ Disagree (2)

Q2. Please provide your name and school. (This information will only be used to contact you for case study purposes. It will not be associated with the data from the rest of the survey.)

Q3 How many years have you been teaching mathematics?

- ❍ 1 to 5 years (1)
- ❍ 6 to 9 years (2)
- ❍ 10 to 14 years (3)
- ❍ 15 to 24 years (4)
- ❍ 25+ years (5)

Q4 Please indicate the current mathematics courses that you teach. (Check all that apply)

- ❑ Algebra 1 (1)
- ❑ Geometry (2)
- ❑ Advanced Geometry (3)
- ❑ Algebra 2 (4)
- ❑ Advanced Algebra 2 (5)
- ❑ PreCalculus (6)
- ❑ Advanced or AP Calculus (7)
- ❑ AP Statistics (8)
- ❑ AP Calculus AB (9)
- ❑ AP Calculus BC (10)
- ❑ Algebra 3 (11)
- ❑ College Prep Math (12)
- ❑ Dual Credit (13)

Q5 Do you have access to an interactive whiteboard (IWB)? (i.e. SmartBoard, Promethean)

- Yes (1)
- No (2)

Q6 How long have you had access to an IWB?

- 1 to 3 years (1)
- 4 to 6 years (2)
- 7 to 9 years (3)
- 10+ years (4)

Q7 How long have you used an IWB? (in years)

- Less than one year (1)
- 1 to 3 years (2)
- More than 3 years (3)

Q8 How many hours do you use the IWB in a week

- Less than 3 (1)
- 4 to 5 hours (2)
- 6 to 7 hours (3)
- More than 7 hours (4)

Q9 On a scale from 1 - 5, rate how competent you are with the IWB?

- 1 - Incompetent (1)
- 2 (2)
- 3 (3)
- 4 (4)
- 5 - Professional (5)

Q10Click to write the question text

	Not At All (1)	Occasionally (2)	Frequently (3)
Write or draw (1)	❍	❍	❍
Overwrite (2)	❍	❍	❍
Color or highlighting (3)	❍	❍	❍
Drag or drop (4)	❍	❍	❍
Zoom (5)	❍	❍	❍
Hide or reveal (6)	❍	❍	❍
Movement or animation (7)	❍	❍	❍
Use of Internet - Non-interactive or video (8)	❍	❍	❍
Use of Internet - Interactive or game (9)	❍	❍	❍
Use of hyperlinks within lesson design (10)	❍	❍	❍
Student use (11)	❍	❍	❍
IWB Gallery (12)	❍	❍	❍
Snapshot (13)	❍	❍	❍
Lesson recorder (14)	❍	❍	❍
Virtual keyboard (15)	❍	❍	❍

Q11 How did you obtain IWB skills and knowledge? (Check all that apply)

- ❑ Vendor (1)
- ❑ Institution (2)
- ❑ Colleagues (3)
- ❑ Professional development (4)
- ❑ Myself (5)

Q12 Describe your need for the following training topics

	No need (1)	Need (2)	Already taken (3)
Technical IWB information and skills (1)	❍	❍	❍
Effective teaching methods and techniques (2)	❍	❍	❍
Finding and designing instructional materials (3)	❍	❍	❍

Q12 Indicate whether you agree or disagree with the following statements

	Disagree (1)	Agree (2)
The IWB helps manage instructional time effectively (1)	❍	❍
The lesson becomes more effective with the IWB (2)	❍	❍
The IWB helps facilitate classroom management (3)	❍	❍
The IWB helps the lesson be more interactive (4)	❍	❍
The IWB helps facilitate classroom discussion (5)	❍	❍
The IWB can be used with various instructional methods and techniques (6)	❍	❍
The pace of the curriculum leaves little time for student use of the IWB (7)	❍	❍
The IWB provides opportunities to make the course content more visual (8)	❍	❍
The way I present instruction has changed since I have begun using the IWB (9)	❍	❍
The IWB helps me use the computer and projector more effective than before (10)	❍	❍

Q13 Indicate whether you agree or disagree with the following statements:

	Disagree (1)	Agree (2)
I believe the IWB helps my students' learning (1)	❍	❍
The IWB makes it easier for students to remember what they learned in class (2)	❍	❍
My students learn faster when I teach with the IWB (3)	❍	❍
The IWB facilitates student learning in groups (4)	❍	❍
The IWB helps students learn structural features or abstract concepts better (5)	❍	❍
The IWB helps students learn procedural steps better (6)	❍	❍

Appendix C
Consent and Assent Forms

IRB Approval 14-0248
THIS FORM VALID 5/16/14 – 5/15/15

Project Title: Dialogic Learning and Self-Explanation in Classrooms Implementing Worked Example Instruction with Interactive Whiteboard Technology
Page 1

Parent/Guardian Informed Consent Agreement

Please read this consent agreement carefully before you decide to participate in the study. Your child will also receive an assent form; please review the assent form with your child.

Purpose of the research study: The purpose of the study is to determine if and how the Interactive Whiteboard (IWB) can support student learning when used to present worked examples instruction in Algebra 1 courses. Your child is being invited to take part in this research study because she/he is currently enrolled in an Algebra 1 course in Fayette County public schools that has been chosen as a case-study classroom.

The primary investigator of the study is currently a student in the Instructional Systems Design doctoral program at the University of Kentucky. This research study will be used as the basis for the PI's dissertation.

What your child will do in the study: Video and audio recordings will be conducted in the single-case study classroom during a lesson that uses the IWB to present worked example instruction in a whole class setting. The researcher will also administer a student pre-test and post-test to students in the classroom. Through observation of the lesson in real time, students' formative assessment exit slips, and input from the classroom teacher, the researcher will select students to interview. Student participant interviews will be used to collect data on self-explanations about the worked example.

Students will be free not to assent, and will not participate in the study. Students who do not assent to be a research subject will still have to participate in the lessons as part of class activities. The lesson is being given to entire class regardless of the research study. The researcher will make very clear that no grade penalty will result from not participating as a research subject. Interactions between researcher and student participants will be limited to audio and video recordings of the worked example lessons, possible whole class observations, and participant interviews after the worked example presentation with those students ONLY with parental consents and student assents. In addition to audio recordings of the single-case study classroom during the lesson, all interviews will be audio recorded. Both sets of audio data will be transcribed and the recordings will be deleted after transcribing.

Video will record the interactions between the teacher, student, and technology. Video angle will obscure students' faces, to take into account any students whose parents did not return permission (or who did not sign the assent. Videos will be storied on a password protected external drive. Video recordings will only be viewed by the PI and PI's academic advisor, Dr. Joan Mazur, during the course of the study. Each participant will be assigned a pseudonym and will only be referred to by pseudonym in study data. The transcription files and video recordings will be stored on an external hard drive which will be kept in a secure filing cabinet in Dr. Joan Mazur's office, Dickey Hall 345, University of Kentucky.

Time required: The case-study classrooms will be observed over the course of 3 lessons.

IRB

Risks: There are no anticipated risks in this study.

Benefits: There are no direct benefits to you or your child for participating in this research study. The study may help us understand how better to use the IWB for Algebra 1 instruction.

Data linked with identifying information:
The information that (you and your child) give in the study will be handled confidentially. Your child's information and your information will be assigned a code number. The list connecting your child's name and your name to this code will be kept in a locked file. When the study is completed and the data have been analyzed, this list will be destroyed. Your child's name and your name will not be used in any report.

Confidential data:
The information that you and your child gave in the study will be handled confidentially. Your data and your child's data will be confidential which means that your name will not be collected or linked to the data.

We may be required to show information that identifies you (or your child) to people who need to be sure we have done the research correctly; these would be people from such organizations as the University of Kentucky.

How to withdraw from the study: If you and/or your child want to withdraw from the study, tell the researcher. There is no penalty for withdrawing.

Payment: You will receive no payment for participating in the study.

If you have questions about the research study :
If your child has questions about the study, please feel free to ask the researcher; my contact information is given below.

If you have complaints, suggestions, or questions about your rights as a research volunteer:
If you have complaints, suggestions, or questions about your rights as a research volunteer, students should tell the teacher and the teacher will contact the staff in the University of Kentucky Office of Research Integrity at 859-257-9428 or toll-free at 1-866-400-9428.

Researcher's contact information:
Researcher's Name: Ellen Bloomfield
1024 Newtown Road
Georgetown, KY 40324
Telephone: (502)370-6324

Faculty Advisor's Name: Dr. Joan Mazur
University of Kentucky, Department of Curriculum and Instruction
345 Dickey Hall
Lexington, KY 40508

Project Title: Dialogic Learning and Self-Explanation in Classrooms Implementing Worked Example Instruction with Interactive Whiteboard Technology
Page 3

Telephone: (859)257-4896

IRB

Agreement:

I agree to allow my child to participate in the research study described above.

I agree to participate in the research study described above.

Signature: ________________ Date: ____________

You will receive a copy of this form for your record

IRB Approval
14-0241
THIS FORM VALID
5/16/14 – 5/15/15

ASSENT FORM

Dialogic Learning and Self-Explanation in Classrooms Implementing Worked Example Instruction with Interactive Whiteboard Technology

You are invited to be in a research study being done by Ellen Bloomfield from the University of Kentucky. You are invited because you are currently enrolled in an Algebra 1 course.

As part of your regular class activities you will be participating in a series of 3 lessons where the Interactive Whiteboard (IWB) will be used to present worked example instruction. Audio and video recordings will be collected of the lesson during your regular class time. If you agree to be in this research study you will be asked to complete a pre-test and post-test over the Algebra 1 material presented in the lesson, and to allow the researcher to include you in the audio and video recordings. In addition, you may be asked to answer some questions during an interview about the worked example lesson.

If you decide you do not want to be in the study, you still have to participate in the lessons as part of class activities, but you will not have to complete the pre-test and post-test, and you will not have to be in the audio or video recordings of the class. No penalty will result from not participating in the study, and your grades will not be affected.

There will be no payment for participation in the study.

Your family will know that you are in the study. If anyone else is given information about you, they will not know your name. A number or initials will be used instead of your name. The video angle will obscure your faces.

If something makes you feel bad while you are in the study, please tell your teacher. If you decide at any time you do not want to finish the study, you may stop whenever you want.

You can ask Ellen Bloomfield questions any time about anything in this study. You can also ask your parent any questions you might have about this study.

Signing this paper means that you have read this or had it read to you, and that you want to be in the study. If you do not want to be in the study, do not sign the paper. Being in the study is up to you, and no one will be mad if you do not sign this paper or even if you change your mind later. You agree that you have been told about this study and why it is being done and what to do.

Signature of Person Agreeing to be in the Study | Date

Name of [Authorized] Person Obtaining Informed Assent | Date

University of Kentucky
Revised 11/25/13

F2.0300
Nonmedical Research Assent Document

IRB Approval
14-0248
THIS FORM VALID
4/29/15 – 4/27/16

Informed Consent Agreement

Please read this consent agreement carefully before you decide to participate in the study.

Purpose of the research study: The purpose of the study is to determine if and how the Interactive Whiteboard (IWB) can support student learning when used to present worked examples/instruction in Calculus courses. You are being invited to take part in this research study because you are currently enrolled in a Calculus course in Fayette County public schools that has been chosen as a case-study classroom.

The primary investigator of the study is currently a student in the Instructional Systems Design doctoral program at the University of Kentucky. This research study will be used as the basis for the PI's dissertation.

What you will do in the study: Video and audio recordings will be conducted in the single-case study classroom during a lesson that uses the IWB to present worked example instruction in a whole class setting. The researcher will also administer a student pre-test and post-test to students in the classroom. Through observation of the lesson in real time, students' formative assessment exit slips, and input from the classroom teacher, the researcher will select students to interview. Student participant interviews will be used to collect data on self-explanations about the worked example.

Students will be free not to consent, and will not participate in the study. Interactions between researcher and student participants will be limited to audio and video recordings of the worked example lessons, possible whole class observations, and participant interviews after the worked example presentation with those students ONLY with consents. Students who do not consent to be a research subject will still have to participate in the lessons as part of class activities. The lesson is being given to entire class regardless of the research study. The researcher will make very clear that no grade penalty will result from not participating as a research subject. In addition to audio recordings of the single-case study classroom during the lesson, all interviews will be audio recorded. Both sets of audio data will be transcribed and the recordings will be deleted after transcribing.

Video will record the interactions between the teacher, student, and technology. Video angle will obscure students' faces, to take into account any students who did not return a signed consent form. Videos will be storied on a password protected external drive. Video recordings will only be viewed by the PI and PI's academic advisor, Dr. Joan Mazur, during the course of the study. Each participant will be assigned a pseudonym and will only be referred to by pseudonym in study data. The transcription files and video recordings will be stored on an external hard drive which will be kept in a secure filing cabinet in Dr. Joan Mazur's office, Dickey Hall 345, University of Kentucky.

Time required: The case-study classrooms will be observed over the course of 3 lessons.

Risks: There are no anticipated risks in this study.

Benefits: There are no direct benefits to you for participating in this research study. The study may help us understand how better to use the IWB for Calculus instruction.

Data linked with identifying information:
The information that you give in the study will be handled confidentially. Your information will be assigned a code number. The list connecting your name to this code will be kept in a locked file. When the study is completed and the data have been analyzed, this list will be destroyed. Your name will not be used in any report.

Confidential data:
The information that you gave in the study will be handled confidentially. Your data will be confidential which means that your name will not be collected or linked to the data.

We may be required to show information that identifies you to people who need to be sure we have done the research correctly; these would be people from such organizations as the University of Kentucky.

How to withdraw from the study: If you want to withdraw from the study, tell the researcher. There is no penalty for withdrawing.

Payment: You will receive no payment for participating in the study.

If you have questions about the research study :
If your child has questions about the study, please feel free to ask the researcher; my contact information is given below. If you have complaints, suggestions, or questions about your rights as a research volunteer, students should tell the teacher and the teacher will contact the staff in the University of Kentucky Office of Research Integrity at 859-257-9428 or toll-free at 1-866-400-9428.

IRB

Researcher's contact information:

Researcher's Name: Ellen Bloomfield
107 Belfair Court
Georgetown, KY 40324
Telephone: (502)370-6324

Faculty Advisor's Name: Dr. Joan Mazur
University of Kentucky, Department of Curriculum and Instruction
345 Dickey Hall
Lexington, KY 40508
Telephone: (859)257-4896

Agreement:

I agree to participate in the research study described above.

Signature: ______________________________ **Date:** __________

You will receive a copy of this form for your record

Appendix D
Visual display of worked example lesson

For each problem, find the average rate of change of the function over the given interval.

1) $y = -x^2 - 2x + 1$; $[-4, -1]$

2) $y = x^2 - 2x - 1$; $[0, 3]$

Mar 26-9:12 AM

For each problem, find all points of absolute minima and maxima on the given closed interval.

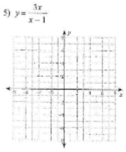
3) $y = x^2 - 6x + 4$; $[4, 6]$

4) $y = -x^2 - 6x - 5$; $[-3, -1]$

Mar 26-9:20 AM

For each problem, find the: x and y intercepts, x-coordinates of the critical points, open intervals where the function is increasing and decreasing, x-coordinates of the inflection points, open intervals where the function is concave up and concave down, and relative minima and maxima. Using this information, sketch the graph of the function.

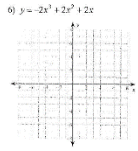
5) $y = \frac{3x}{x-1}$



Mar 26-9:20 AM

For each problem, find the: x and y intercepts, x-coordinates of the critical points, open intervals where the function is increasing and decreasing, x-coordinates of the inflection points, open intervals where the function is concave up and concave down, and relative minima and maxima. Using this information, sketch the graph of the function.

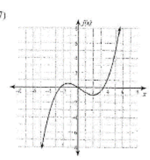
6) $y = -2x^3 + 2x^2 + 2x$

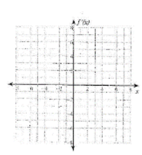


Mar 26-9:22 AM

Given the graph of $f(x)$, sketch an approximate graph of $f'(x)$.

7)

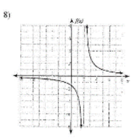


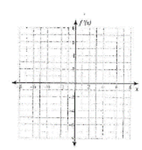


Mar 26-9:22 AM

Given the graph of $f(x)$, sketch an approximate graph of $f'(x)$.

8)



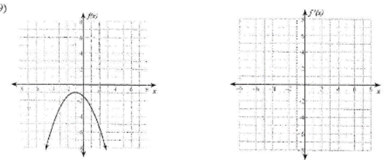


Mar 26-9:23 AM

1

Given the graph of $f(x)$, sketch an approximate graph of $f'(x)$.

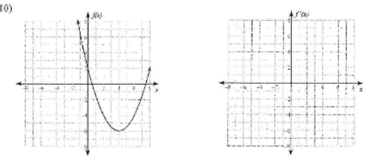
9)



Mar 26-9:23 AM

Given the graph of $f(x)$, sketch an approximate graph of $f'(x)$.

10)



Mar 26-9:24 AM

For each problem, find the x-coordinates of all points of inflection, find all discontinuities, and find the open intervals where the function is concave up and concave down.

11) $y = -x^4 - 2x^3 + x^2$

12) $y = \frac{x^2}{3x - 6}$

13) $y = \frac{x^2}{2} + x + \frac{3}{2}$

Mar 26-9:25 AM

For each problem, find the open intervals where the function is increasing and decreasing.

14) $y = -x^3 + 4x^2 - 3$

15) $y = \frac{2x}{x - 2}$

16) $y = \sin(2x)$; $[-\pi, \pi]$

Mar 26-9:26 AM

For each problem, find the values of c that satisfy the Mean Value Theorem.

17) $y = \frac{x^2}{2} + 3x - \frac{1}{2}$; $[-6, -4]$

18) $y = -2x^2 + 16x - 31$; $[3, 5]$

Mar 26-9:27 AM

A particle moves along a horizontal line. Its position function is $s(t)$ for $t \geq 0$. For each problem, find the velocity function $v(t)$, the acceleration function $a(t)$, the times t when the particle changes directions, the intervals of time when the particle is moving left and moving right, the times t when the acceleration is 0, and the intervals of time when the particle is slowing down and speeding up.

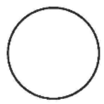
19) $s(t) = t^3 - 23t^2 + 120t$

Mar 26-9:28 AM

2

Solve each related rate problem.

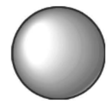
26) Water leaking onto a floor forms a circular pool. The radius of the pool increases at a rate of 4 cm/min. How fast is the area of the pool increasing when the radius is 6 cm?



Mar 26-9:31 AM

Solve each related rate problem.

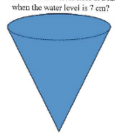
27) A spherical snowball is rolled in fresh snow, causing it to grow so that its radius increases at a rate of 3 in/sec. How fast is the volume of the snowball increasing when the radius is 3 in?



Mar 26-9:31 AM

Solve each related rate problem.

28) A conical paper cup is 10 cm tall with a radius of 30 cm. The cup is being filled with water so that the water level rises at a rate of 4 cm/sec. At what rate is water being poured into the cup when the water level is 7 cm?



Mar 26-9:31 AM

For each problem, find all points of relative minima and maxima.

29) $y = \frac{x^2}{2x - 2}$

Mar 26-9:33 AM

For each problem, find all points of relative minima and maxima.

30) $y = x^4 - 2x^2 - 1$

Mar 26-9:34 AM

For each problem, find the values of *c* that satisfy Rolle's Theorem.

31) $y = 2x^2 - 8x + 8$; $[1, 3]$

Mar 26-9:35 AM

Appendix E
Screenshots of Content Data Analysis

Talk categories, themes, subthemes, and definitions identified in the data

Line	Subject	Transcript	Turn Type	Information	Question	Answer	Repair	Confirmation	Type of Talk: CONTENT	Conceptual	Procedural	Introduce	Test-taking advice	Engage prior knowledge/ learner attention	Agreeance	Correction	Type of Talk: PURPOSE	Refine/exp and conditions	Explicate/infer consequences of action	Impose goal/define purpose of action	Give meaning to quan. expressions
93	S6	All right, so now we're going to distribute straight through this, and we get the area is equal to 250X minus 3-1/2s		x							x										x
94	S6	alrighty, and now we will take the derivative of that		x							x									x	
95	S7	Yes						x							x						x
96	S7	Yeah, a prime is equal to 250 -		x							x										
97	S7	Can we, like add a new page? (Laughter)			x						x										
98	T	Scroll down				x					x										
99	S7	Oh, I don't like this (laughter)		x							x										
100	T	Scroll on the other side		x							x										
101	S7	(laughter)																			
102	S9	Hey - there's "extend page" at the bottom		x										x							
103	S6	Let's do that thing		x										x							
104	S7	Oh		x											x						
105	S7	Okay, so we'll do the derivative.		x							x									x	
106	S6	Okay, so A prime is going to be equal to 250 minus 3X, and we can just solve it out real quick.		x							x										x
107	S7	Oh yeah, Oh, and then we can use the other equation		x										x					x		
108	S6	Yeah, where it was..uh…						x							x						
109	S7	….Where it was like 2x plus y equals-			x									x							x
110	S6	3Y equals 4?			x											x					x
111	S6	Umm…3x plus..			x											x					x
112	S1	..3x plus 4y				x										x					x
113	S7	That one, that one thankfully you get this (laughter)						x							x						
114	S10	So is this where A prime equals zero?			x						x										
115	S7	Yes				x									x						x
116	S7	Yeah, so it's like , your solving like you're like your critical points on your number line. So,		x						x								x			
117	S7	Does that make sense? So like that's how we got that.		x							x							x			
		If you plug back in the 500 minus 3 times that X, it's all really gross, but eventually you get 125 over 2, as a Y value and 250 over 3 as the x value.		x							x										

IWB use categories, themes, subthemes, and definitions identified in the data

Line	Subject	Transcript	Board Action		Board Action: FUNCTION	Action - No Board	Reference	Write or Draw	Color	Overwrite	Highlight	Hide or Reveal	Techincal Difficulties	Board Action: PURPOSE	Conceptual	Procedural	Direct Attention	Advice	Reference Prior Informations
93	S6	All right, so now we're going to distribute straight through this, and we get the area is equal to 250X minus 3-1/2s	write procedure step - sc.18	x				x								x			
94	S6	alrighty, and now we will take the derivative of that																	
95	S7	Yes	write procedure step - sc.20	x				x								x			
96	S7	Yeah, a prime is equal to 250 -	write procedure step - sc.20	x				x								x			
97	S7	Can we, like add a new page? (Laughter)																	
98	T	Scroll down	student adjusting page to allow for more room																
99	S7	Oh, I don't like this (laughter)																	
100	T	Scroll on the other side																	
101	S7	(laughter)	Scrolling																
102	S9	Hey - there's "extend page" at the bottom	Ref feature - sc.20				x										x		
103	S6	Let's do that thing																	
104	S7	Oh	Extends page																
105	S7	Okay, so we'll do the derivative.	write procedure step - sc.21	x				x	x							x			
106	S6	Okay, so A prime is going to be equal to 250 minus 3X, and we can just solve it out real quick.	write procedure step - sc.21	x				x								x			
107	S7	Oh yeah, Oh, and then we can use the other equation	write procedure step - sc.21	x				x								x			
108	S6	Yeah, where it was..uh...	write procedure step - sc.21	x				x								x			
109	S7	....Where it was like 2x plus y equals-	write procedure step - sc.21	x				x								x			
110	S6	3Y equals 4?	write procedure step - sc.21	x				x								x			
111	S6	Umm...3x plus..	write procedure step - sc.21	x				x								x			
112	S1	..3x plus 4y	write procedure step - sc.21	x				x								x			
113	S7	That one, that one thankfully you get this (laughter)																	
114	S10	So is this where A prime equals zero?																	
115	S7	Yes																	
116	S7	Yeah, so it's like , your solving like you're like your critical points on your number line. So,	write conceptual representation - sc.22	x				x							x				
117	S7	Does that make sense? So like that's how we got that.	write procedure step - sc.23	x				x								x			
		If you plug back in the 500 minus 3 times that X, it's all really gross, but	write procedure step - sc.24	x															

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Academic Degrees

Masters of Education (MEd)	Eastern Kentucky University, May 2006 Educational Leadership
Bachelor of Arts (BA)	Transylvania University, May 1993 Mathematics and Secondary Education

Work Experience

January 2015 – Present	Adjunct Faculty Midway University Midway, Kentucky Course taught: EDU 201 Technology in the Educational Setting
August 2014 – Present	Director of Instructional Technology Midway University Midway, Kentucky
May 2014 – May 2015	Instructional Design Consultant University of Kentucky College of Public Health Southeast Center for Agricultural Injury Prevention Lexington, Kentucky
May 2006 – August 2014	Mathematics Teacher Henry Clay High School Lexington, Kentucky
August 2001 – May 2006	Mathematics Teacher Bryan Station Traditional Middle School Lexington, Kentucky
August 1997 – May 2001	Mathematics Teacher Goose Creek High School Goose Creek, South Carolina

Professional Experience

AECT International Convention
October 2016.
Poster Presentation. *"Dialogic Learning and Self-Explanation in Classrooms Implementing Worked Example Instruction with Interactive Whiteboard Technology"*

Faculty Development Week: Road to Redesign
August 2016
Designed and presented a weeklong conference for faculty development to expose faculty members to active learning and alternative methods of instruction that result in a more meaningful learning experience for students

Association of Independent Kentucky Colleges and Universities
January 2016 – Present
AIKCU Technology Symposium committee member. Assisted in the planning and operations of the annual AIKCU technology conference.

Kentucky Council Postsecondary Education: Distance Learning Steering Team
September 2015 – Present
Convened the Authentication Work Group and published white paper for university Provost on SACS-COC Standard 4.8.1 Authentication.

Spring Education Research Conference
April 2013
Presenter. *"Using the Interactive Whiteboard for Worked Example Presentations"*

TiER 1 Performance Solutions
January 2009
Instructional design consultant/Subject matter expert. Performed task analysis, developed course objectives for supplemental content CD-rom.