How do Interactive White Boards Affect Participation in the Mathematics Classroom?

by

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Abstract

Interactive whiteboards (IWBs) have become common fixtures in mathematics classrooms around the world. They have provided new opportunities for educators to impart learning upon students. Drawing on Stephen Hegedus’ and William Peneul’s work on participation structures with SimCalc MathWorlds™, this research study examines the effect IWBs have on participation structures within the mathematics classroom. Specifically, the objective of this research was to determine if IWBs can elicit participation and engagement amongst students. To accomplish this, two Grade 9 mathematics classes in a Suburban Vancouver secondary school were videotaped and analyzed over six lessons (12 classes total) that incorporated IWBs. The videos were then analyzed to determine the impact the IWB had in creating participation structures and what challenges were encountered. The findings suggest that IWBs can positively affect participation by facilitating gestures, providing dynamic images that allow for students to visualize future movements, and encouraging student-student discussion.

Keywords: Interactive Whiteboard; Participation; Mathematics; Gestures; Visualization
For my wife, Kate,

who has supported me throughout this process

and has been at my side throughout.


For my son Liam,

who never fails to bring a smile to my face every day.
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1. Introduction

Advances in Interactive Whiteboard (IWB) technology are changing the way content is taught in the mathematics classroom. However, to date, limited research has been conducted to evaluate the effectiveness of these novel tools. This research study examines the role that IWBs play in the participation structures and overall engagement of students in two Grade 9 mathematics classrooms.

Prior to undertaking this study I had been using IWBs in my math classrooms for almost 5 years both in Ontario and in British Columbia. Having previously worked at a school that had a partnership with a leading IWB manufacturer, I was provided with considerable training in their operation and ways to incorporate their use in the mathematics classroom. With this first-hand practical experience, I witnessed the potential that IWBs held in improving student learning. However, prior to this study I had not placed much emphasis in how participation structures could be developed through their use in the classroom. In the context of this thesis, participation structures refer to the rights, roles, and responsibilities of students in the classroom, particularly in the context of “who can speak what and when?” (Hegedus & Peneul, 2008)

While working at a secondary school in the Greater Toronto Area, a colleague and I began to investigate how we could increase the communication
abilities of our students as well as improve the participation structures in our classrooms. Our goals were to increase students’ abilities to clearly express their thoughts and to increase the amount of student-to-student discussion in classes with respect to what was occurring in the lesson and what students were learning. Our focus did not explicitly include the use of technology although we both regularly used various technologies in our classrooms.

A key reason for our attempt to increase the participation structures in our classrooms came from our observations that many students experienced the learning of mathematics as being an exercise in copy and repeat. Students would copy the notes from the board, and then they would repeat numerous questions of a similar nature, however, they would rarely engage in discussions of the content, other than to answer questions posed on the board. Their ability to communicate their mathematical knowledge was limited, and we wanted to change that. This study is an extension of that idea combined with a novel approach using technology from a pair of researchers. It was not until reading an article by Stephen Hegedus and William Penuel entitled ‘Studying new forms of participation and identity in mathematics classrooms with integrated communication and representational infrastructures’ (2008) during my Master’s studies that the idea arose for a study to examine the use of IWBs to facilitate participation structures in the mathematics classroom. In their study, Hegedus and Penuel used graphing display calculators and the SimCalc MathWorlds™ software to examine how students communicate their thoughts and how this
technology could be used to increase student-to-student communication in connected classrooms. Through my interest in the use of IWBs in mathematics, as well as my interest in changing the participation structures within the classroom, I developed the idea to examine how, if it all, IWBs can be used within the mathematics classroom to create these participation structures as well as examining student engagement in mathematics classrooms.

This study is meant to address the general lack of participation and engagement that I have witnessed in many mathematics classrooms, both others and my own, by incorporating a new technology that is already in many mathematics classrooms today. In the context of this thesis, I refer to participation as an active role a student takes in speaking, answering questions, and approaching the IWB, while the word engagement refers to a more passive form of participation. An active, focused, and participative class of students is important in that it enhances the learning environment and encourages students to discuss their ideas and thoughts. These discussions are crucial in students solidifying their understanding of concepts as well as correcting any errors in understanding that they may have had without such discussion. This thesis will examine the role that IWB’s can play in bringing about such discussions.

Using Hegedus and Penuel (2008) as a guiding point, and using an IWB, I developed a study to videotape six of my Grade 9 mathematics lessons and analyse the videotapes for any evidence of participation structures in order to determine how the IWB did or did not aid in the process. As I was teaching two
sections of Grade 9 mathematics at the time, this resulted in a total of 12 lessons being taped and analysed. In what follows, I present current literature on IWBs concerning their impact in secondary mathematics, an overview of my methodology, an analysis of the taped lessons as well as some important reflections and ideas that have been generated throughout this process.
2. Literature Review

This literature review begins with a general overview of the progression of technology within the mathematics classroom. I then present some ways in which technology has affected the teaching and learning of mathematics and what effect it has on student engagement and participation. Next, the IWB is introduced. What is it, how does it work, and what has led it to become so prevalent (Lee & Wizenreid, 2009) in schools and mathematics classrooms? Current research on IWBs is presented next, in particular the focus will be on ways in which IWBs have been proven effective in the learning of mathematics, their effects on student motivation and engagement, as well as the need for comprehensive training of teachers so they may effectively use them in the classroom. Following this, participation structures and engagement within the context of the mathematics classroom are defined. As this study focuses heavily on these two aspects, the leading research will be presented in order to create of a framework for the study carried out for this thesis.

2.1. Technology in the Mathematics Classroom

The evolution of educational technology over the past fifty years has resulted in a need to continually evaluate and study its effects on student learning in the mathematics classroom. Seymour Papert’s book Mindstorms (1980) was one of the earliest in-depth looks at how technology influences the
learning that can take place in mathematics classrooms. Kaput (1992) continued with his work on technology and math education at a time when technology was limited in its capability as well as its presence in the classroom. Some of the limiting factors that he identified were the lack of software of sufficient quality as well as the fact that at the time, computers were too difficult for the average teacher to use in addition to a lack of pre-service preparation for teachers.

Much has changed in the last two decades and the use of technology in the mathematics classrooms has become much more commonplace. Although it can be argued that students agree that it is better learning mathematics with technology rather than without (Pierce, Stacey, & Barkatsas, 2007), some research has found that in fact technology plays only a marginal role in many mathematics classrooms (Becker, 2000; Cuban, Kirkpatrick, & Peck, 2001), however, the explanation for this varies. As Goos and Bennison (2008) suggest, merely providing access to technology and software and making them available to students does not result in teachers and/or students being able to use them appropriately or when necessary. Becker (2000), on the other hand, acknowledges that although the number of teachers who use computers as a primary resource in classrooms are in the minority, in those cases where they are being used on a frequent basis, students are benefiting greatly from it. Becker also addresses the fact that in mathematics, teachers feel it is important to cover a wide breadth of topics rather than fewer topics in depth. This results in the
teacher being less inclined to focus on technology given the perceived time investment even if the technology is accessible.

In addition, merely using technology in a mathematics lesson does not mean that the lesson will be any more effective or that students will learn any better. As Silk, Higashi, Shoop, and Schunn (2010) claim, just because math is present in an activity doesn’t mean that students will actually learn any math. This goes against the general belief of many teachers that merely integrating mathematics into technology results in students becoming more mathematically competent. The integration of technology in mathematics education has been a topic of great discussion and focus in the last three decades, however, recent research has shown that access and use of technology is important, however, these aspects will not necessarily produce results on their own (Silk, Higashi, Shoop, & Schunn, 2010). Becker (2000) notes that individual teachers proficiency and comfort with various technologies has a profound impact on the amount of computer and software-assisted activities used throughout the year. Becker also identifies mathematics as one of the subject areas that is most affected by teacher proficiency and comfort levels. How technology is integrated into the classroom and who has access to it are both integral to their impact in the classroom.

A key point recently emerging around the use of technology is the positive correlation between the amount of professional development a teacher receives with technology and a teacher’s ability to successfully and meaningfully employ
its use within the classroom (Goos & Bennison, 2008; Miller & Glover, 2007; Zevenbergen & Lerman, 2008). That is, the more teachers have been trained in the use of technology the more successful they are at using it in a relevant and effective manner. The literature highlights a gap between the funding of technology and the funding of professional development to effectively use that technology. As school districts and ministries of education continue to invest in the technology itself, they appear to neglect the value and importance of effectively training teachers and students to use the technology in pedagogically relevant ways.

Becker (2000) points to the fact that the integration of technology in classrooms can also be linked to a teacher’s philosophy of teaching. Becker identifies those teachers who are transmission oriented, teachers who believe that understanding comes about through direct instruction and guided practice, are less likely to employ technology in meaningful ways. In contrast, teachers whose practice aligns with a constructivist theory of education, where understanding comes from a student’s effort to integrate new information with prior beliefs and understandings, are more inclined to incorporate technology into their teaching practices. In addition, the manner in which these two groups employ technology is profoundly different. Transmission oriented teachers tend to use technology as a means reinforce skills while constructivist oriented teachers are more apt to use technology communicate ideas and learn to collaborate.
The literature about the interactivity of and engagement with technology in the classroom raises some important points. Fredricks, Blumenfeld, and Paris (2004) view engagement as having three components – behavioural, emotional and cognitive engagement. The authors define behavioural engagement as following rules, level of attention, asking questions, and contributing towards class discussions. Emotional engagement refers to reactions by students such as boredom, interest, and anxiety. Cognitive engagement refers to the psychological investment in learning, preference towards challenge, as well as a desire to go beyond the base requirements. Much of the analysis of engagement in this study will centre on behavioural engagement.

In Kahveci and Imamoglu’s (2007) review of the literature on interactive learning in mathematics education they find that computer software has dramatically evolved over time. In the late 1990’s Kirsch (1997) claimed that computer interfaces were rarely interactive because the programs that were used at the time were not intelligent enough to behave as tacit partners. The user must always adapt to the computer, as the computer is not able to adapt to the user. Kahveci and Imamoglu found that in the decade since Kirsch made this claim, software has evolved significantly and now is now much more interactive than it had ever been. They cite two studies of interactive software programs, MathCAL (Chang et al, 2006) and LaborScale (Adiguzel & Akpinar, 2004) where researchers found a significant difference between pre and post-test results. In both cases the software is able to react and adapt to the inputs of the user.
The use of technology has been a major focus of researchers over the past few decades with the introduction of numerous new technologies as well as the increase use of technology in mathematics classrooms. The majority of the research points to benefits of incorporating these technologies into curriculum design and delivery. However, the manner in which these technologies are incorporated appears to be an aspect that has become of great importance. Merely having the technology present and/or using it in non-meaningful ways is ineffective. Instead, there need to be substantial planning and thought put into their use in the classroom in order to enjoy many of the learning benefits that they offer. The next Section explores this idea with IWBs specifically.

2.2. **Interactive Whiteboards**

Interactive whiteboards (IWB) were introduced to educational settings in the 1990’s. They were originally designed and developed for the business sector, but were then expanded to educational environments. The initial high cost along with the unproven benefits of the IWB resulted in an initially relative slow rate of adoption by schools in Canada. However, in the past 5 – 7 years, the rate of adoption has increased and it is common to see IWBs being used in schools as prices have begun to drop and both teachers and students have come to embrace their presence in the classroom. Their use in the mathematics classroom has been especially strong for reasons that are mentioned later in this Section.
IWBs are large screens that are usually mounted on a wall (although there are also portable versions), in which an image is projected onto the board from an LCD projector, which is connected to a computer. The IWB is also connected to the same computer via a USB cable and thus the three pieces of equipment are linked together. A unique feature of the IWB is that the screen is touch-sensitive and allows the user to control the computer by touching the IWB screen in the same way that many cell phones and tablet computers are. The computer is usually controlled by the IWB through the use of one’s finger or special pen that allows one to write on top of any image on the screen or by one’s finger.

The size of the IWB can vary, however, they are much larger than any computer interface that students have previously been accustomed to. The use of IWBs transforms what was previously designed and directed toward the individual, their computer screen, and turns it into a display aimed at social use. Students no longer need to gather around one small screen while an individual interacts with the computer, as the image is now large enough for the whole class to view. In addition, the actions and commands needed to use the device and/or program have also been made public. By interacting directly with the screen, students and teachers can see exactly how the user is operating the device/program to create the image that is projected on the board.

The open display and use of the IWB is very different to previous uses of technology in the mathematics classroom. Previously students worked on individual computers and as such their work was individual in nature and rarely
shared, much like that of their notebook work. If someone wanted to view what another had done, they were required to go over to that person’s screen to view it. If a student was asked to demonstrate their work on a screen with the aid of an LCD projector, the image could be projected, however, it would be difficult to understand how that image came to be as it was not possible to see the commands being delivered to the computer. That has all changed now with the introduction of the IWB.

IWBs allow for public viewing of both the image and the commands in a simultaneous fashion. For example, prior to using the IWB, when demonstrating the concept of constructing an equilateral triangle using *The Geometer's Sketchpad* I have to do the construction at my computer using my mouse. It requires me to verbalize each movement explicitly, and often I have to move between my computer and the screen to point to an item or a menu selection so that students are able to follow along while constructing the required circles and finding their intersection point. However, with the IWB this can all be done at once and students can easily follow along and do the construction themselves at their computer by watching my movements and seeing exactly what I am doing in each step, including the required actions in the program itself.

There have also been many accessories that have been created specifically for IWBs that are used in the classroom as a means to engage students. Products such as response clickers, wireless slates, and document cameras have all been widely used in educational settings with IWBs. Response
systems put a small device the size of a television remote control in the hands of each student and allows them to wirelessly submit a response to a multiple-choice question. A unit that is connected to the teacher’s computer enables the teacher to display the responses in real time on the IWB screen and to collect the responses to measure understanding. In most cases teachers are able to display the data anonymously so that individual students are not identified on screen, although the data that the teacher receives privately can identify individual students. These data can be used in a formative basis to identify which students understand the concepts and those that do not. These data can also be used in a summative manner by assigning a grade to each student based on the number of correct responses.

Wireless slates have been developed which allow students to write on a small rectangular shaped slate that can be positioned at their desk and which wirelessly transmits what is happening on the slate and projects it to the screen of the IWB. This reduces the amount of time needed for students to approach the board and also allows for students who may not be able or who do not want to approach the IWB in such a public format to participate nevertheless. For now, these wireless slates are limited in their functionality as they can only transmit one way; from slate to IWB. This means that the image that is seen on the IWB screen is not visible on the slate. However, with the recent introduction of Apple’s iPad and Blackberry’s Playbook, it isn’t difficult to imagine a similar device that can interact with IWBs in the near future.
Finally, the recent introduction of document cameras has addressed the issue of resources that are not in digital form. Although educational materials and texts are continually becoming more digitized, there are still a large number of resources in the educational field that are paper-based and thus not suitable for use with IWBs. A document camera changes this by placing a hard copy of a resource under the camera. The camera then projects a picture of the resource onto the IWB screen and enables the user to write over top of it using the pens on the IWB. This document can then be saved in a digital format.

Many of these devices have been developed specifically in response to the needs of educators to further enhance and improve the learning experience with IWBs as well as providing the manufacturers with another revenue stream after a school has purchased IWBs for their classrooms. As technology develops and new ideas are generated there will surely be more of these devices on the market.

With the recent surge in the use of IWBs in educational settings (Lee & Wizenreid, 2009), there is interest from researchers and academics to assess their effectiveness in the classroom based on the increasing number of studies examining IWB’s. Academics from the United Kingdom, the greatest users of IWBs (Futuresource Consulting, 2010), have been leading research that aims to measure the benefits, if any, attributable to IWBs. This is largely due to the early adoption and support towards IWBs by the UK government (Lee, 2010). The rate of adoption can vary quite widely in Canada as not all school districts are
supporting the technology, and there is not a national effort to increase their adoption in classrooms that I know of as there is in other countries.

Since their introduction, IWBs have become increasingly common in educational classrooms in many developed countries. The United Kingdom (UK) has IWBs in over 70% of classrooms while Denmark, the Netherlands, the United States, Australia, Mexico, Ireland, Portugal, and New Zealand each have over 20% of their classrooms outfitted with IWBs (Futuresource Consulting, 2010). These rates are much higher than any other new technology that has been introduced in recent years so early in its lifetime (Lee & Wizenreid, 2009). The blackboard, perhaps the most similar piece of technology to the IWB, took decades before it was common in classrooms (Kidwell, Ackerberg-Hastings & Roberts, 2008), while the personal computer, took much longer than the IWB to gain such a presence within educational classrooms.

2.3. **Current Research on IWBs**

The past decade has seen a dramatic increase in the amount of research undertaken that focuses on the use of IWBs as well as their impacts in educational settings. Despite this increase, the technology is still relatively new and as such the amount of information as well as the scope of many studies is still somewhat limited. This section summarizes the current research on IWBs in relation to their use in mathematics classrooms, their effects on learning, as well as their influence on the motivation and engagement levels of students.
2.3.1. **IWBs in Mathematics Classrooms**

The use of IWBs in the mathematics classroom has been especially strong as compared with other new educational technologies and may be attributed to numerous factors. Perhaps one of the biggest reasons for this early and strong rate of adoption is that the IWB essentially works just as a blackboard does. It is a public display, allows for teachers and students to write on it, and provides a visual presentation that a lesson will usually centre around. Although much more technologically advanced than a regular blackboard at it’s core, the IWB is a digital blackboard; a tool that all teachers are familiar with and comfortable using. The importance of this is the notion that teachers find change difficult, and in particular change in their teaching habits. Jacobs et al (2006) found that although teachers genuinely believe that their teaching practices have changed, when studying teachers’ ability to address the new NCTM standards in the United States, it was found that many teachers had not changed at all. Hiebert (2000) in an earlier study, came to the same conclusion; despite a teacher’s best intentions as well as their perceptions that they have changed their teaching practice, in fact, in most cases they changed little or nothing at all.

This may be a determining factor in why teachers may have taken on the IWB at such a quick pace. The IWB and the blackboard are so similar in nature that little would need to change in their teaching practices to incorporate the IWB in to their lessons. In fact, a teacher could use an IWB exactly as they use their
blackboard. This would not be using the IWB anywhere near its full potential; however, they could begin using it immediately.

To facilitate the switch between a regular blackboard and an IWB many of the companies selling IWBs also provide lesson templates to assist teachers in making the transition. The industry leader in IWB sales, Smart Technologies, has even developed math-specific add-ons to their software to further enhance the use of the IWB in the mathematics classroom. Most manufacturers have also developed lesson banks in which teachers can upload a lesson created specifically for the IWB for others to download and use in their classrooms.

Despite the potential, the introduction of IWBs themselves does not guarantee any benefits to the learner. It is important that educators use them in an effective manner so that they offer more than the regular LCD projector already does. Clark-Jeavons (2005) identifies three levels of interactivity when it comes to the use of IWBs in mathematics classrooms. The first level is low interactivity. At this level, the IWB is used in a manner that is not significantly different from what could be accomplished with an LCD projector. For example, the use of the IWB to advance from one slide to another in presentation software such as PowerPoint (i.e. as a mouse or keyboard) is not an interactive use of this tool. The second level identified is medium interactivity. At this level the user (either teacher or student) is able to control software for whole class teaching and discussion to illustrate a concept. An example is demonstrating how the three medians of a triangle intersect at the same place, the centroid, by using a
dynamic geometry software package. The third and most advanced level is high interactivity. At this level students are able to do more than just demonstrate a concept using a software package; they are also able to interact with it. An example is to take the vertex of the triangle in the previous example and drag it along the board thus changing the shape of the triangle. As the triangle changes students are able to see that the medians move as well, however, they will still all intersect at one point, the centroid. Clark-Jeavons’ levels of interactivity are used in the current research to explain any participation structures created in the lesson.

The IWB is significantly different from previous technologies used in mathematics classrooms. Sinclair and Jackiw (2005) situate the IWB in the context of their three waves of Information Communications Technology (ICT) in the mathematics classroom. Each wave represents a different vision offered by the technology in terms of ‘where learning occurs, by or between whom and how’. Each wave becomes progressively more intricate in the relationships it fosters. The first wave of ICT focuses on the relationship between the learner and the mathematics. These technologies focus on each individual’s acquisition of mathematical ideas and pay little or no attention to any of the relationships between teacher, other students and the class as a whole. The second wave of ICT began to include the relationships with the teacher as well as the curriculum into the use of the technology, such as dynamic geometry software. The third wave, which the authors include the IWB within, also includes the relationships
between ‘the teacher, the classroom, classroom practices and the world outside of the classroom’. The IWB is considered to be within the third wave of ICT as it offers geographic democratization through its ability to offer a common space that all students can use in a classroom compared to other technologies where each student usually must possess a unit to take part, such as graphic display calculators (Sinclair & Jackiw, 2005). This ‘geographic democratization’ is a core element of the research study carried out for this thesis. It is the ability for all students to be involved and use the IWB that is expected to generate the student-to-student discussion and participation structures that the study aims to create and analyse.

When the blackboard was introduced it transformed mathematics education and the way mathematics was learned in schools. Prior to the blackboard, mathematics was a private affair. Students either worked individually, or as was more common, students actually did not ‘do’ much mathematics. The study of mathematics was about memorizing theorems and rules. With the introduction of the blackboard, mathematics could then be done and not just memorized. The introduction of the blackboard changed how mathematics was learned in many more ways as well. Now that mathematics was being taught using the blackboard, teachers were able standardize the mathematics as well as have greater control over the discussions around the concepts. The blackboard enabled teachers to present a concept to each student at once. This meant that every student saw the exact same markings on
the blackboard and enabled the teacher to expect that every student would present their mathematics in the same manner. Having identical markings on every student’s slate as what was presented on the blackboard also provided a new manner of discussing the mathematics. The discussions were now directed at the presentation on the blackboard and thus were no longer individual discussions, but a common discussion of the concept or problem. This presented a fundamental shift in the learning and teaching of mathematics. The blackboard had a profound effect on the participation structure of the mathematics classroom. No other technology that has been introduced in the mathematics classroom has had such a profound effect on participation, until perhaps now. Although the IWB has not had such an effect on participation, many feel as though it has the potential to do so in the not so distant future. This role that the IWB has on participation structures in the classroom is the main focus of this study.

The introduction of blackboards first occurred within a select few colleges and universities. As the popularity of the boards increased, both with students and teachers, the newly created ‘common schools’ (public schools) of the 1830’s also adopted the blackboard (Kidwell, et al., 2008). In the early 1900’s the blackboard was taken for granted as it had spread to most classrooms in virtually all American and Canadian schools.

The IWB has seen a similar but much more rapid rate of adoption. The IWB has been in educational classrooms for less than 20 years and already they
can be found in many American and Canadian schools with more being added every year. 15 years after their introduction, they can be found in almost 20% of Canadian classrooms and have become the focus of numerous studies in an attempt to measure their effectiveness in the classroom. Just as the blackboard revolutionized the mathematics classroom in the early 1800’s, the IWB has the same potential today. The IWB enables mathematics to become dynamic and active, two qualities that were hard to facilitate with the blackboard. Students can now see various mathematical relationships at work and have the power to adjust, manipulate, and create these images and relationships for everyone to see in real time.

2.3.2. Research literature related to the effect of IWBs on learning

The literature on the benefits of IWB use in mathematics classrooms is relatively recent and different reports conflict about their effectiveness in educational settings. An early study on the uptake of IWBs in secondary schools by Glover and Miller (2001) found that the novelty of the IWB, the quicker pace of lessons, as well as the visual cues provided through their use led to increased motivation based on a survey of teachers and students at the time. The authors gathered the responses of teachers from one school in England as well as interviewing a third of their survey respondents in determining the levels of student motivation. However, the same study also found that there was considerable frustration with their use when the technology was not functioning properly. This feeling of frustration and the effects that non-functioning
technology has on teachers and students tend to be a common theme mentioned in many published articles (e.g., Zevenbergen & Lerman, 2008; Quashie, 2009; Lee, 2010).

While initially students may be more engaged due to the novelty factor of IWBs when they are first introduced some studies have concluded that IWBs may decrease the interactivity of lessons. The use of IWBs can potentially lead to more whole class teaching, resulting in a reduction of the amount of student-to-student conversations as well as the amount of work in small groups (BECTA, 2004). Smith, Hardman, and Higgins (2006) found that teachers who use IWBs tend to assume a position at the front of the class and spend less time on group work. Through their observations of nearly 200 Year 5 and 6 classes in the United Kingdom over a two-year period, these researchers were able to view each teacher deliver multiple lessons with and without the use of an IWB. This led to the observation that during the IWB lessons teachers positioned themselves at the front of the room for a greater portion of the class as well as incorporating less group work into their lessons. The issue of authority and control of the IWB is also of concern to some researchers. The teacher assumes control of the IWB and because they tend to be more skilled and knowledgeable in the use and functioning of IWBs they assume a form of ownership over them (Zevenbergen & Lerman, 2008). In this study the authors analysed taped lessons from nine schools in Australia as well as teacher interviews to determine the impact of ICT’s in classrooms. Zevenbergen and Lerman go on to note that
this ‘predominance of the teacher’s ownership of the artifact militates against active interactions, open questions and intellectual challenge’. Pupils’ lack of expertise slows down the pacing, which puts at risk the increased motivation of pupils that comes with the IWB. The authors noted that in their study the IWB was almost exclusively used for the introduction of a concept and then not used for the remainder of the class with little or no interaction and doing so reinforces the teacher’s ownership over the technology. The IWB is the one technology within schools where teachers tend to be much more knowledgeable than the students with their use.

In another study Pratt and Davison (2003) found that the visual and kinaesthetic aspects of the IWB are not enough to ‘encourage the fusion of conceptual and visual aspects of children’s figural concepts’ when the activities used only examine the visual transformation of figures without any concentration on the definition and meaning of such figures. This study looked at a class of 11-12 year-olds in the UK who were using dynamic geometry software as well as the IWB to investigate the properties of a kite. The authors found that students had difficulty in constructing and recognizing a kite since they often drew shapes, rather than constructed them geometrically. The study highlights the importance of ensuring that students are not just completing various tasks with technology without also focusing on the underlying definitions and understandings required to ensure that there is authentic learning occurring in such activities.
Glover, et al. (2007) assert that the IWB has the greatest impact on teaching and learning when it is used in the third of their three stages of interactivity, the enhanced interactivity stage. In this stage teachers "integrate concept and cognitive development in a way that exploits the interactive capacity of the IWB" (p. 10). In their study, the authors videotaped 50 lessons by 34 different teachers as well as conducted interviews with each teacher. The authors noted that as teachers became more confident with the technology and as they progressed to the third level of interactivity, they became more aware of a variety of learning styles. All of the teachers at this level spoke of presenting concepts in different ways. The authors assert that students appeared to gain more from these lessons, as they appeared to gain from additional visual representation compared to a solely oral explanation. Although there is a recognized benefit to learning from the IWB, the authors point out that it is still the quality of teaching that ensures student progress and that the IWB is not of benefit without such quality teaching.

These studies do not rule out the ability to increase the participation and engagement levels of students, however, they do raise some concerns that, if not addressed, could actually work contrary to why they were introduced in the first place.

2.3.3. Student Motivation and Engagement

There have been numerous qualitative and quantitative studies that have examined the relationship between the use of IWBs in the classroom and the
effect they have on student motivation. The majority of these studies have indicated an increase in student motivation when using an IWB in the mathematics classroom. Thompson and Flecknoe (2003) used classroom observation methods to focus on lessons that used mathematics in conjunction with IWBs. Through the use of a tracking sheet and observation for a one week period, they found that students were more attentive and classroom disruptions became less frequent in these lessons than in lessons that did not include the IWB. Slay, et al. (2008), used a combination of teacher interviews and observations in their assessment that using technology, including IWBs, were positive factors for student motivation. Both teachers and students were interviewed throughout the course of the study to measure perceptions of the benefits and drawbacks of IWBs. They cited the visibility of the screen as well as the ability to incorporate interactive activities as being the most identified factors by both students and teachers.

Torff and Tirotta (2009) used a quantitative study of 773 students split into a control group and treatment group to assess the role of the IWB on student motivation. Their findings were mixed in that students seemed to report slightly higher levels of motivation. These motivation levels were even higher when teachers strongly supported the use of IWBs. Overall they could not say for sure that the increase in motivation was directly attributable to the IWB.

Both Burden (2002) and Levy (2002) interviewed teachers to assess their perception of students' motivation levels during IWB assisted lessons. In both
cases the teachers reported increased motivation on the part of students, which they saw as being attributed to the use of IWBs.

In all of these studies there appears to be reports of increased student motivation when using IWBs in mathematics lessons, however, in most of these cases it cannot be established that these increases are directly attributable to the IWB. Other aspects such as better designed lessons, or increased teacher enthusiasm could have led, or at least contributed, to the reports of increased motivation. This study will attempt to go beyond the self-reporting characteristic of many of these studies by videotaping lessons and analysing them afterwards in order to look for key indicators of participation and engagement from the two classes. Whereas many studies contain a form of ‘bias’ through their use of interviews, this study attempts to eliminate this by assessing participation in a manner that does not rely on teacher or student self-reporting.

2.3.4. Teacher Training

An area that has also seen considerable research is the relationship between teacher training in the use of IWBs and their effectiveness and/or rate of adoption in the classroom. One of the primary reasons suggested to explain the underperformance of IWBs in creating interactive and participatory lessons is the ability of the teacher to effectively use them. As Morgan (1994) notes, tools by themselves will not transform pedagogy regardless of their potential. In order for the IWB to be the change-maker that many anticipate it to be, teachers must accept it and they must be trained to use the technology in new and creative
ways to increase the interactivity in the mathematics classroom. Smith, Higgins, Wall and Miller (2005) warn that despite the potential of IWBs to have a positive impact in the classroom the technology should be used in unique and creative ways above and beyond that which is possible when teaching with normal whiteboards and projection methods.

The data from the UK suggests that there has been very little pedagogic change by teachers in mathematics classrooms with IWBs (Office for Standards in Education, 2008). Miller and Glover (2010) assert that where this is the case it is often because of the lack of technical competence with IWBs on the part of the teachers. They go on to propose that mathematics teachers need to have a basic level of technical skills and proficiency with IWBs before they are able to alter their pedagogic approaches. Lee (2010) suggests that an often-overlooked aspect of technology is that if teachers do not use it then they will also prevent student use. Contrary to Glover and Miller, however, Lee’s notion is that what is important is the normalization of the digital by the whole staff and not how well they actually use it. It seems, however, that this is a minority view as many other studies also highlight the importance of teachers being able to use IWB technology in meaningful ways in order for them to be considered any more effective than other digital technologies. (Clark-Jeavons, 2005; Glover et al., 2007; Slay et al., 2008)

Research has also shown that pre-service teachers are much more apt to embrace IWB technology when compared to experienced teachers (Miller &
Glover, 2007). The authors note that teachers who are introduced to IWBs from the beginning of their teacher training are more apt to adopt the technology in their classroom. Many experienced teachers find it difficult to adopt new technologies such as the IWB due to the need to learn how to become proficient in their use. It is often more difficult for many experienced teachers to radically change the way in which they teach as compared with younger or new teachers who have grown up in the digital age. Prensky (2001) classifies this divide as being between Digital Natives and Digital Immigrants. In the context of education, many teachers are digital immigrants, we bring our traditions and ways of doing things into the digital age, always keeping some aspects of our previous context (the non-digital learning environment) in our teaching. In contrast, Digital Natives have grown up in a digital world and can’t understand these past tools and techniques Digital Immigrants use in their teaching practices. As IWBs are installed in more classrooms and the Digital Immigrants retire, making way for Digital Native teachers to enter the profession, the use of IWBs will be more prevalent and the need for them to be used in an effective manner will be even more important.
3. Theory and Methodology

3.1. Theoretical perspectives

A major focus of this thesis is the role that the IWB has in influencing participation amongst students in a mathematics classroom. As such, the ideas of participation and participation structures are addressed in this section in order to define the various types of participation that are being examined in this research study. Within the context of this study, participation structures refer to the various rights, roles and responsibilities of participants in a setting (Hegedus and Peneul, 2008) while participation refers to the active role a student takes in speaking, answering questions, and approaching the IWB.

3.1.1. Participatory classrooms

Generally, the most common participation structure found in mathematics classrooms had been the teacher-student-teacher episodes whereby the teacher asks a question, a student responds and the teacher evaluates the response. This form of dialogue is still common in most classrooms today. Cazden (2001) referred to these episodes as initiation-response-evaluation (IRE). These interactions between students and teachers reinforced the role of the teacher as being the authority of knowledge who then evaluates each student on their ability to absorb such knowledge. However, it has been shown that when these roles are changed somewhat so that students feel as though they can assume some of
these authoritative roles of the teacher such as generating and assessing information as well as monitoring progress, it has a dramatic pedagogical effect on students (Cazden & Beck, 2003, Palincsar & Herrenkohl, 2002). As such, it appears that participant structures that create symmetry between students and the teacher result in a more balanced environment between authoritative and persuasive discourse (Tabak & Baumgartner, 2004).

Tabak and Baumgartner (2004) took these findings and developed three participant structures that they could classify various science lessons into depending on the nature of discussions between teacher and student as well as the role that each teacher took and the roles that they conferred upon their students. These three structures, Monitor, Mentor, and Partner, attempt to classify episodes based on the teacher-student relationship, the discourse pattern, the nature of prompts, as well as the nature of interaction of both the teacher and students. The Monitor participant structure is characterized by an initiation-response relationship between student and teacher, whereby the teacher sets the tasks and ensures they are carried out, while the students’ role is to carry out the actions and report on their progress. Most Monitor episodes models that of the IRE format discussed earlier. In the Mentor participant structure, the model of IRE is replaced by IRF (initiation-response-feedback) discourse pattern. The switch from evaluation to feedback in the discourse pattern provides room for negotiation, interpretation, and adaptation of ideas rather than being tested or evaluated as is done in the IRE pattern. In the Mentor structure, the teacher attempts to align a student’s thinking with that of
mathematical norms through feedback and questions. The final participant structure identified by Tabak and Baumgartner, the Partner structure, is similar to the Mentor structure, however, in the Partner structure, the teacher assumes the role of peer and/or partner in an investigation. The teacher assumes the same role as the students and do not present themselves as the authority. They are a genuine member of the group. The communication structure also changes in that it no longer follows a teacher-student-teacher format. There can be multiple student turns in a row as well as multiple teacher turns.

Hegedus and Peneul (2008) took Tabak and Baumgartner’s work on participant structures in science and applied it to the math classroom. The authors emphasize the importance of authority to speak amongst students in creating ‘fluidity’ within the classroom based on Tabak and Baumgartner’s assertion that when multiple students are authorized to speak, turn taking tends to be less structured. Hegedus and Penuel claim that when more equitable participation structures exist the teacher’s role shifts as does their discursive moves in a manner that advances student thinking. It is on this basis that the research study undertaken for this thesis is based on. By creating a participant structure that encourages and promotes student turn-taking and ownership with the IWB, it is hoped that students will experience a richer learning experience. In a similar fashion as to how Hegedus and Penuel created rich discussions amongst student with their use of SimCalc Mathworlds and graphing display calculators, it is anticipated that through the use of IWBs and select software, similar participant structures will emerge. In order to examine the various forms
of positioning that the students engaged in, as well as their issues of identify, Hegedus and Peneul also examined the use of deictic markers by students. Since identify and positioning were not central to my research question around participation, I did not pursue this kind of analysis.

3.1.2. Non-verbal forms of participation

While Hegedus and Penuel (2008) focus on the verbal forms of participation that occur in the classroom, there are also non-verbal ways that students use to contribute their ideas and show their engagement. One of these ways, which has received a lot of attention in the mathematics education literature during the past decade, relates to the use of gesture.

“Gestures are hand movements that accompany and are directly tied to speech.” (Goldin-Meadow, 2004) Gestures by both students and teachers are a way in which explanations and meaning can be communicated. Goldin-Meadow asserts that the different ways in which students gesture may actually indicate their level of understanding as they can convey thoughts that are not expressed in speech. In the context of IWBs, student gestures may provide information pertaining their understanding as well as engagement in a lesson. In another study, Cook, Mitchell and Goldin-Meadow (2007) found that requiring students to gesture while learning a new mathematical concept helped retain the knowledge they had gained. Conversely, for those who did not gesture but only spoke, there was no impact on the retention of knowledge. In both studies, researchers have been able to confirm the importance of gestures in acquiring new knowledge and
in particular within a mathematics classroom. These studies demonstrate that gestures are not be overlooked when examining students’ participation in various tasks as well as in their ability to explain their thoughts and ideas.

Edwards (2009), in a study that included interviews with elementary teachers around the concept of fractions, discovered that many teachers used gestures that mimicked the use of manipulatives used in their teaching practices. That is, when attempting to explain a concept, the gestures that accompanied their verbal explanation were similar to how they would move about the various manipulatives they used with their students to teach the topic. This particular idea is important as gestures that imitate the actions one would employ to control various software programs on an IWB could also indicate learning.

It is not uncommon for students to use gestures in their explanations and reasoning within a mathematics classroom. They are an everyday occurrence in the classroom whether or not the lesson is participatory, with technology and without. Therefore, it is important to note that the gestures examined in this study are limited to ones in which it appears as though the IWB had a direct influence in manifesting. If such gestures are indeed encouraged from the use of the IWB, it may be that the IWB is a catalyst for student participation as they allow students to make meaning of the concepts presented through the actions required to demonstrate them on the IWB.
3.2. Methodology

3.2.1. Research Objectives

The primary goal of this research was to identify if the use of IWBs in the mathematics classroom could elicit participation and engagement amongst students. In addition to the primary goal, I was also interested in how to incorporate the use of IWBs in lesson development. The two objectives are complimentary to each other. In order to elicit the participation of students, the lesson must be appropriately designed and incorporate the IWB in meaningful and pedagogically relevant ways.

3.2.2. Research setting

The design of this research was to videotape two Grade 9 mathematics classes that I was teaching at the time in order to determine if the use of an IWB would result in increased participation during the lesson. I chose the Grade 9 course because at the time I was teaching two different sections. Having the opportunity to view two different groups of students react to the same lessons and activities would allow for a greater ability to determine the effectiveness of the IWB on participation levels in class.

The study took place in a suburban secondary school within the lower mainland of British Columbia, Canada. With a population of over 1400 students, the school was considered to be a medium to large sized secondary school within the district. At the time of the study the school had two mobile IWBs that
were used infrequently since their purchase three years prior. As such, students were not accustomed to having their teachers deliver lessons/activities with IWBs, and the vast majority of students had not touched an IWB before this course.

3.2.3. Study timeline

The study took place in late March and early April of 2010. Prior to the start of the study ethical approval was sought and obtained from the Surrey School District and the Department of Research Ethics at Simon Fraser University. A pilot lesson was created and delivered to each class in early March 2010 in order to introduce the study to students, test-run a lesson to establish what information each camera could capture, and establish correct camera placement in the classroom. The data collection phase of the study took place from March to April 2010. Video analysis was conducted over the summer and fall of 2010.

3.2.4. Pilot study

Prior to the start of the study, the IWB was used with both classes on an almost daily basis for approximately two weeks in order to familiarize students as much as possible with it’s use in the classroom as well as providing an opportunity for students to use the IWB themselves before the study took place. The purpose of this was to minimize or eliminate the novelty effect of a new technology. That is, when a new and possibly exciting technology is introduced to students they can be distracted from the purpose of using the software and
instead focus on the novelty of the product. In the case of the IWB, students often want to touch it just to see how it works rather than to learn the material at hand. By introducing the IWB before the study students had the opportunity to touch the IWB and to become comfortable and accustomed to its use in the classroom by the time the study lessons took place.

3.2.5. Data collection

Each class was videotaped using two video cameras. The first camera was situated at the rear of the classroom and was primarily focused on the IWB to capture what was occurring on it. The second camera was situated near the front of the room and was positioned such that it would capture the students in the class in order to view any hand gestures and/or movements by the students while they were speaking.

In total 6 lessons were videotaped over a span of two units. Three lessons were from a unit on circle geometry while the other three lessons were from a unit on algebra and linear relations. The lessons were chosen for their potential to elicit participation through the use of the IWB, therefore, the three lessons from each unit were not necessarily done in succession of each other. For example, the lessons on circle geometry were chosen because it was anticipated that the use of The Geometers’ Sketchpad along with the IWB would provide sufficient opportunities for students to use the IWB, and enhance their learning of the concepts with the use of both the software and the IWB. In the case of the last three lessons, each lesson was chosen based on what programs and resources
were available. Online applets were used in these classes as they provided an interactive environment for students that could be exploited through the use of the IWB. In recognition of the fact that IWBs are not a panacea in the classroom and that they must be used in appropriate situations, (Miller, Glover, & Averis, 2004) lessons deemed as having the potential to create the participation structures desired for this study were selected. Each lesson was designed so that the delivery of content was primarily facilitated through the use of the IWB. The lessons were designed so that students were asked to respond to certain activities taking place on the IWB as well as to have students use the IWB themselves during the lesson. The lesson design stage of the research project proved to be one of the more difficult phases. It was not difficult to develop activities in which students could use the IWB, however, it proved challenging to ensure that the activities and materials used fit into the overall goal of the lesson while at the same time allowing various participation structures to emerge. Although the it was hoped that such participation structures would emerge naturally, knowing that this was a key goal of each lesson resulted in the design of the lesson facilitating some of these structures artificially. As mentioned in the previous chapter, one of the greatest challenges to the use of IWBs in the mathematics classroom is the ability to use it in pedagogically relevant ways. This proved to be more difficult than previously anticipated, and as will be discussed later in the chapter on key lessons, this was perhaps not always achieved in each lesson.
Various software was used with the IWB for these lessons. In the first three lessons of the study, the dynamic geometry software program, *The Geometer’s Sketchpad* version 5 (GSP5), was used. GSP5 works well with IWBs as it has a feature that allows for all points to be enlarged thus facilitating grabbing and dragging these points on an IWB where the precision is not always as great as when a mouse is used. GSP5 assisted students in their construction and investigation of circle properties in this unit. GSP5 had been used with these classes prior to the study, albeit in a limited fashion. The last three lessons incorporated the use of on-line applets to demonstrate linear relationships and solving algebraic equations.

### 3.2.6. Data analysis

The data collection phase of the study resulted in twelve videos of the classes (two for each of the six lessons). I reviewed each video in two stages. In the first, the videos were reviewed to assess overall impression and themes, and to gain familiarity of the lesson from the perspective of an observer. It was important to gain this perspective prior to further analysis in order to add to the perspective I already had as a teacher in the environment. Following this, the videos were re-reviewed with the specific aim of identifying episodes where: i) the use of the IWB encouraged dialogue between students, as opposed to between myself and the students, and ii) where the visual and interactive characteristics of the IWB led to student understanding of the mathematical concept either through their comments or their gestures. These episodes were
noted with a brief description of the scenario and time marker of the video to allow for further review and analysis. After noting these episodes, these video clips were then reviewed again in further detail, coded, and transcribed.

Each of the episodes was coded into one or more of four possibilities; visualization, gestures, student-student dialogue, and key points. Visualization refers to any comments that a student made that seemed to suggest that the IWB helped in creating a visual impression that then led to an idea or comment of significance. If a student used hand or body movements when explaining a thought or answering a question, the episode would receive a gesture coding which was then further analyzed to see if the gesture was of any significance. Episodes whereby there was student-student dialogue were also coded and then analyzed in the context of the types of participation structures that existed in the various lessons. Finally, any comment that stood out as having significance in terms of the IWB influencing its development were also noted.

Using the theories and findings presented above, I then analyzed these transcriptions in terms of the role of the IWB in creating the participatory structures identified.

3.2.7. Research ethics

Prior to videotaping a proposal with the objective, procedures, and anticipated benefits of the study was submitted to the school district for approval to conduct the study within their schools. A similar proposal was also submitted
to the Director of Research Ethics at Simon Fraser University for approval. Upon receiving approval from both parties, consent forms were distributed to both students and their parents/guardians as each student was required to agree to being videotaped and a participant of the study. Overall, nearly 80% of all students and their parents/guardians agreed to take part in the study. The two cameras were set up in such a way that those students who were not taking place in the study were not captured on video. In addition, any audio recording of students who did not consent to the study was not used in the analysis.

The identities of each student have been anonymized in this dissertation in compliance with the agreements between the author and the school district as well as the Department of Research Ethics at Simon Fraser University. All videotapes of the lessons will be destroyed following completion of the thesis work as was agreed to between all parties.
4. Analysis and Interpretation

4.1. Video Analysis

Upon video-taping each lesson, the videos were then analysed and key episodes in each lesson were identified. These episodes were such that an important element of participation in the context as defined in this thesis was evident. Examples include episodes in which it appeared that the students’ communication (whether by gesture or in speech) was mediated by the use of the IWB. For example, if they pointed or referred to the IWB or if they mimicked something they had seen happen on the IWB, or if they engaged directly with the IWB.

Each of these episodes was then transcribed and studied to determine the nature of participation and how it relates to the learning of mathematics with IWBs. Within this chapter the most salient examples are described with respect to what took place and in terms of how it relates to participation and learning in the mathematics classroom with IWBs. I will discuss later on the frequency of these episodes relative to the overall time span of the lesson, as well as the context of their occurrence (when during the lesson, what parts of the lesson, etc). These episodes are grouped together in terms of the nature of the student actions, such as hand gestures, student-student interactions, etc.
4.2. **Lesson Descriptions**

The first three lessons that were taped for this study were from a unit on circle geometry. The Grade 9 mathematics curriculum in British Columbia requires that students explore various properties of circles under the Shape and Space curriculum organizer. The prescribed learning outcomes for this unit as defined in the Grade 9 curriculum documents are as follows:

**Measurement**

C1 solve problems and justify the solution strategy using circle properties, including:

- the perpendicular from the centre of a circle to a chord bisects the chord
- the measure of the central angle is equal to twice the measure of the inscribed angle subtended by the same arc
- the inscribed angles subtended by the same arc are congruent
- a tangent to a circle is perpendicular to the radius at the point of tangency

(BC Ministry of Education; 2008)

The first lesson is an investigation of inscribed angles within a circle using the dynamic geometry program, *The Geometer’s Sketchpad* (GSP). After introducing some basic circle concepts, students were asked to hypothesize what they would expect to happen in various cases and then attempt to prove their hypothesis using the IWB and GSP. Students were asked a number of questions such as what would happen if we moved the endpoint of an angle along the
circle, or what would happen if we moved the vertex of the angle below the endpoints. Students then provided their thoughts on what they hypothesized before approaching the IWB to test whether their hypothesis was correct or not by demonstrating on the IWB using GSP. The second lesson is an investigation of chords and their perpendicular bisectors in order to problem solve in various contexts. In this lesson, students were presented with various word problems in which they needed to use their knowledge of chords to solve the problem using GSP on the IWB. The last lesson is a carousel of problems relating to circle geometry. The class was split into 6 groups with each group rotating around the room to solve various word problems that incorporate circle geometry. One such problem was to be solved using the IWB. As in the previous taped lesson, this problem focused on student’s knowledge of chords and their ability to solve a problem using such knowledge, again with the IWB and GSP. The video from this lesson focused on one specific problem (which is outlined later in this chapter) and the students’ use of the IWB in solving it.

The final three taped lessons were from a unit on linear relationships. In this unit students investigated solving simple algebraic equations as well as the concept of slope to graph and analyse linear equations. The prescribed learning outcomes for this unit also fall under the Shape and Space curriculum organizer:

**Patterns**

- generalize a pattern arising from a problem-solving context using linear equations and verify by substitution
- graph linear relations, analyse the graph, and interpolate or extrapolate to solve problems

**Variables and Equations**

-model and solve problems using linear equations

(BC Ministry of Education; 2008)

The fourth lesson (first from this unit) focused on solving simple algebraic equations using manipulatives, both physical and virtual. Two online applets were used in this lesson to demonstrate the use of manipulatives virtually. The first is an applet from the National Library of Virtual Manipulatives entitled Algebra Balance Scales (http://nlvm.usu.edu/en/nav/frames_asid_324_g_4_t_2.html?open=instructions&from=category_g_4_t_2.html), while the second program enabled students to arrange algebra tiles with the IWB as they would on their desk (http://my.hrw.com/math06_07/nsmedia/tools/Algebra_Tiles/Algebra_Tiles.html). The lesson focused on students’ ability to arrange algebra tiles to represent equations and then to use this representation to aid them in solving for the unknown variable. The fifth lesson was an introduction to the concept of slope using an online program, Line Rider (www.linerider.com), to predict the outcome of an animated character travelling on a sled down a course constructed by students. The lesson focused on what slope is as well as how slope can be viewed in a context outside of the classroom. The sixth and final lesson examined how to draw linear relations, first by reviewing how to plot points on the
Cartesian plane using another applet from the National Library of Virtual Manipulatives, Point Plotter (http://nlvm.usu.edu/en/nav/frames_asid_331_g_4_t_2.html?from=category_g_4_t_2.html), and later drawing linear relationships using Sketchpad. The lesson drew on the previous two taped lessons and brought both the concept of slope and the ability to rearrange equations together in order to represent linear relations in two forms, algebraically and graphically.

4.3. Key Episodes

Throughout the recorded lessons there were episodes where students’ actions or statements indicated that the IWB had an impact on developing or reinforcing their ideas around the concepts being covered. These episodes have been grouped into three categories for the purpose of this chapter, each of which focuses on a particular type of mediation; visualization, hand gestures, and student-to-student dialogue. When analyzing the taped lessons, these were recurring aspects that were identified. Visualization of Movement is analysed since in some episodes, when students’ are explaining how they developed an idea they mention that they visualized it in their mind. These episodes are analysed to determine what role the IWB played in their creation. Hand gestures in themselves are not out of the ordinary in a mathematics classroom, however, what was noticed was that many of the gestures being used by students mimicked the gestures used to control the IWB in each of the classes. Student-to student dialogue was a key focus of this research. Building on the work of
Hegedus and Peneul (2008), who focused on similar types of dialogue, these conversations are analyzed to determine the IWB’s role in facilitating them.

4.3.1. Visualization of Movement

The first taped lesson in this study focused on inscribed angles in a circle. The lesson began by examining two inscribed angles sharing the same endpoints. Throughout the unit, the primary software that was used was Sketchpad version 5 (GSP5). Students were somewhat familiar with the Sketchpad program as it had been used in class prior to this study. The software was chosen for use in this study based on students familiarity with it as well as its ability to provide students with the opportunity to witness first-hand how the theorems that they are learning can be verified. Traditionally, this unit has been taught at the school with a photocopied booklet in which there are a number of ‘rules’ that students must know (i.e. memorize) and then a number of worksheets that they can complete to practice these concepts. All of the diagrams were static and there was no way for students to confirm or explore how these concepts behave in a dynamic way. GSP allows students to explore and investigate each theorem by manipulating the diagrams and moving angles and chords around the circle to determine how it relates back to the theorem being learned.
Students had been at the IWB moving the vertices of both angles to learn that as the vertex moves about the circle the angle does not change (figure 1). They were given the one limitation that the vertex had to remain above the two endpoints. I then asked the class what they thought would happen if the vertex was moved along the circle so that it was now below the endpoints.

**Teacher:** “So what do you think is going to happen as point B or point D is moved below points A or C?”

[7 second pause]

**Student 1:** “The angle is going to get bigger” (the original angle had been acute, thus when the vertex was moved along the circumference to below the endpoints, the angle became obtuse).

**Teacher:** “The angle is going to be bigger. Ok, why do you think that?”
Student 1: “...well I just kind of saw it in......”
Teacher: “You saw it in?”
Student 1: “I imagined it in my mind.”
Teacher: “Ok, you imagined it in your mind. Awesome.”

This was an important episode in the lesson as it suggests that the prior use of the IWB allowed the student to visualize episodes that had not yet occurred. The dynamic nature of the graphing software along with the ability for students to physically manipulate the image so that everyone can witness what is happening to the image along with the result, allowed this student to then take the next step and visualize what would happen next before it even took place. This is an important aspect of IWBs in mathematics classrooms. Prior to IWBs the images that students would see would either be static, or any movement that took place would not be accompanied by the inputs needed to create the movement. For example, if a dynamic geometry software program was being used then students could view the movements; however, they would not explicitly see what the user was doing to create that movement. However, now that students can see both the input and the result in real time, it provides them with the opportunity to then take all of this information and use it to predict the result of future events. Guzman (2002) identifies visualization as being an important tool in mathematics as it is from the image that methods and concepts are formed. Students are often asked to represent situations in a diagrammatic format; however, this can be a real struggle for many students. The IWB, in conjunction with math specific software, can facilitate the process of visualization
and assist students in making these important connections. The ability for this student to ‘see it in her mind’ should assist her in the ability to take a static image and make it dynamic in her brain in order to solve future problems.

The ability to visualize the concept or activity can also aid in increasing participation within a classroom. When students are able to understand and conceptualize the question, they are better prepared to participate in class discussions or answer questions. It also assists in creating the partner participant structure identified by Tabak and Baumgartner (2004) that was discussed in Chapter 2. The teacher, in situations like this, better positions the student to talk about the event rather than just answer directed questions. The discussion is no longer constrained by the IRE format in which very little discussion is present.

Another event where visualization assisted students in building their knowledge occurred in the same lesson. The class was investigating inscribed angles and we had just finished looking at the property whereby as you move the vertex of the angle around the circle, the angle measurement does not change. I then wanted to investigate what happens when I add another inscribed angle with the same endpoints. It was drawn so that the two vertices were apart from one another. The first angle’s measurement was displayed on the IWB, however, the second angle had yet to be measured. In the previous Section on gestures, this episode was used as one of the students responded to a question and was using hand gestures. She was attempting to explain why the two
inscribed angles were the same. After her response I attempted to get students to prove this by asking:

**Teacher:** “How do we know that angle ABC and ADC are exactly the same measurement?”

[after an 18 second pause a student responds]

**Student 1:** “Because if we move point D up to point B, it would be the same angle.”

**Teacher:** “Ok, can you show us that that is the case?”

At this point the student approaches the board and drags point D around the circle until it is at the same position as point B as can be seen in figure 2. This was a significant episode as together, the IWB and GSP allowed the student to show that the two angles are the same by dragging the vertex of one to the vertex of the other. As the two angles share the same vertex and endpoints, they must be the same angle. This was possible through our prior discovery that as the angle moves about the circle, it’s measure does not change, as well as the ability of the IWB to drag the vertex so that the entire class could see how this works. Previously, students would have had only static diagrams to view and they would have to take the teachers word when they were told of this property. GSP allows the student to manipulate the image dynamically while the IWB makes these actions public to her classmates. In addition, the language that the student uses by stating; “if we move point A” is dynamic in nature, similar to what Sinclair and Yurita (2008) found in their research which was mentioned in the theoretical framework.
Figure 2: Investigating Inscribed Angle

Note: the student drags the vertex of one inscribed angle so that it overlaps the other, thus showing that the two angles share the same measure.

These are two examples of visualization that were evident in the taped lessons. These episodes highlight the potential benefits of using an IWB in conjunction with GSP to assist student learning. Although they provide a glimpse
into the potential of IWBs, there were only two clear episodes in the data collected, and both came from the same lesson. In Chapter 5, I will discuss the relatively low occurrence of these visualization episodes.

4.3.2. **Hand Gestures**

Throughout the first lesson students can be seen using a number of hand gestures when speaking to the class. Many of these gestures seem to model the same movements that they witnessed through the use of the dynamic geometry software that was being used. This is important, as it appears to indicate that the use of the IWB has had an impact in the way in which students are able to visualize or understand the topic at hand as well as provide students with the ideas and confidence in participating in class discussions. The goal of this research is to determine if IWBs have an effect on participation in the classroom. When many of the episodes whereby students are speaking include gestures that mimic the hand movements used to control the IWB, it has led me to conclude that these episodes of participation were initiated through the use of the IWB. These episodes continue throughout the six lessons that were taped and appear to occur in a variety of settings, whether it is large class discussions or in small groups. A number of these episodes are included to further demonstrate this point.

In the first three taped lessons, *Sketchpad* was used frequently to illustrate the key concepts in the circle geometry unit. In the first lesson *Sketchpad* was used to illustrate inscribed angles as well as properties of cyclic quadrilaterals.
On numerous occasions the images are dragged or animated to demonstrate what effect moving the vertex of an angle has on the angle measurements and the relationship between two or more angles. While responding to questions or providing ideas, students can often be seen gesturing with their hands in movements that emulate what had previously happened with the dynamic geometry software.

*Figure 3  Two inscribed angles*

In one episode a student had just returned to her seat after having been at the IWB demonstrating a concept when she raised her hand to answer a question. The class was exploring inscribed angles within a circle and we were examining two angles (angles ABC and ADC) that shared the same endpoints. I had drawn two inscribed angles, one with its vertex halfway between the
endpoints, and a second angle with its vertex very close to one of the endpoints (figure 3). I had then posed the question ‘Do you think angle ABC is greater than, less than, or equal to angle ADC?’ The student, who had just been at the front of the class using the IWB to investigate what happens as the vertex of one inscribed angle moves about the circumference of the circle, raised her hand to respond. She said;

‘because what we did before is we moved the points (the vertex) and so they stayed the same so for these we just moved positions’. [As the student is talking she is rotating her hand in the same fashion that was required when using the IWB]

Figure 4. Gesturing that mimics use of the IWB

![Figure 4](image-url)  

*Note.* The arrow indicates the student’s use of hand gestures in her explanation.

As can be seen in the screen shot above, the student is looking at and mimicking the gesture required to rotate the vertex while saying this. The prior use of the IWB allowed this student to not only visualize why these two angles
should be the same measurement, but it also seems to have promoted the use of hand gestures similar to how one would use the IWB to rotate the vertex around the circle. As previously mentioned, the hand gestures seem to indicate that the use of the IWB played a role in developing her thoughts, and as such, assisted her in her ability to actively participate in class.

This happens again, much later in the lesson, when the same student asks a question. At this point in the lesson we were focusing on the idea that opposite angles in a cyclic quadrilateral sum to 180 degrees. Just prior, I had emphasized the importance of proving that an angle is 90 degrees and not assuming that it is because it looks like it is. While she was asking whether the two opposite angles could both be equal to 90 degrees, once again the student seemed to be virtually moving the vertices of the two angles to place them where she thought they would be at right angles. It almost appears as though the hand movements were creating an image within her head based on what she had seen and done with the IWB so far in this lesson.
Student: “So if angle ABC is equal to 90 degrees then angle ADC would also have to be equal to 90 degrees?”

Teacher: “Yes exactly. If angle ABC is 90 degrees then we could prove that the opposite angle is 90 degrees as well.”

These two episodes demonstrate how the IWB can create a highly interactive environment as outlined by Clark-Jeavons (2005) in her assessment of how IWBs can be used within mathematics classrooms. Not only are students touching and dragging points to facilitate their learning, they are also gaining the ability to go one step further and use this knowledge in order to predict what will happen in untested situations.
The use of hand gestures to convey the actions students would perform on the IWB to explain their thoughts appears in almost all of the lessons that were taped. During the third lesson in which small groups are rotating around the room, hand gestures can be seen on many of the groups at the IWB. In this lesson students are in small groups and talking within their group to solve a problem. No longer is there a whole class discussion being mediated by the teacher, students are in groups of five and are able to converse with each other in a more intimate and informal setting.

This lesson had students solving a circle geometry problem using the IWB and Sketchpad. The problem that students were asked to solve was:

*In a circle with radius 10cm, chord AB is 12cm long and chord FG is 16 cm long.*

*Which chord is closer to the origin of the circle? How do you know? How far is each chord from the origin of the circle?*

Throughout the lesson hand gestures are once again used by a number of students. These gestures appear to be a product of the use of the IWB in that these gestures seem to mimic the hand motions needed to control the IWB. In the first episode two members of the group are attempting to explain to the student at the IWB what he needs to do in order to complete the next step. After telling the student at the board what they think needs to happen, he is still unsure and asks why. One of the two students who had just explained their thoughts
then approaches the board and attempts to show the other by gesturing to a point on the board to create a right triangle.

**Student 1:** “You need to draw a right angle.”

**Student 2:** “What, like this?”

(Student 2 gestures where he would draw the right angle)

(Student 3 then picks up a pen and gestures to another part of the circle where she thinks the triangle should be drawn while saying something that is not picked up by the microphone)

(Student 1 then draws a line from the midpoint of a chord to approximately the midpoint of the radius.)

**Figure 6 Carousel Activity**

(The two other students are quick to correct him and use gestures to show him where the line should be drawn – from the midpoint of the chord to the point where the radius touches the circumference of the circle.)
(Student 1 then proceeds to draw the correct line to create a right angled triangle)

In this episode the ability to manipulate the diagram and show the first student working at the board how the right triangle could be created (they need the right triangle to solve for a length) results in the student at the board to continue in his attempt to solve the problem. Had this not been possible, it may have resulted in the student at the board not being able to continue if they were unable to make that connection and see how the original diagram could have been altered slightly, resulting in a diagram that could lead to a solution.

In all of these episodes the IWB appears to provide students with the ability to reflect on what had happened to predict what actions could result in the
desired outcome for each particular case. The ability to subsequently move a point, or alter a diagram as they had explained provides instant feedback as to whether they were correct and why or why not. Students have the ability to drag points with Sketchpad and the IWB and immediately see the outcome, while the IWB also provides a public arena for all of this to happen. It also appears as though the IWB is the catalyst in eliciting participation from students in that many of their hand gestures model the gestures used to control the IWB. The IWB seems to have occasioned these particular episodes of participation, on account of its dynamic display as well as its shared space for interaction.

4.3.3. **Student-to-Student Dialogue**

In the fifth of the taped lessons, students are introduced to the concept of slope before they learn about linear relationships and equations. The purpose of the lesson is to have students begin to think of slope in a situation that they can relate to. During this lesson students will use the IWB in conjunction with an online web based program called Line Rider (www.linerider.com). Line Rider is an online application that allows students to draw various paths and then send an animated character down the path to see whether they will survive the course or not. This application was chosen for the lesson as it requires students to consider the slope of the line, the effect of sudden and abrupt changes in the line on the toboggan as well as the speed of the toboggan based on all of these aspects. In addition, all of this is accomplished in a fun environment in which the concept of slope is never really spoken about in mathematical terms. The lesson
is meant to be an introduction and have students begin to consider the concept in general terms.

This lesson created a number of student-to-student interactions. In one episode a student had completed drawing a path and during the journey down the path the character flew off of a bump. The following interaction took place in response to the outcome:

**Teacher:** “What is wrong with this point?” (pointing to a peak in the line where the rider fell off)

**Student 1:** “It’s too high?”

**Student 2:** “No it’s sharp!”

**Student 3:** “It goes down all at once so the rider feels like…..like they’d get scared.”

*Figure 8 Identifying the problem in the path*
In this episode, the first student (the creator of the line) isn’t sure in her response as to whether it is the height of the hill that was the problem (she poses her response more as a question than an answer). Another student immediately speaks up and says that it is not the height but rather the rapid change in direction from up to down that the line takes (‘it’s too sharp’) while another student attempts to articulate the same thought differently by saying that the line goes down all at once. Throughout this interaction numerous other students are putting forth their ideas as well, however, many other students’ voices were not picked up clearly enough by the microphone to know exactly what is being said.

It appears as though these student-student interactions are in part a result of the use of the IWB as all students were able to relate to the context and because of this, were more willing to put forward their ideas and opinions. The IWB facilitated this as it allowed the rest of the class to comment in real time to the student drawing the line as they witnessed the line taking shape. It also elicited numerous explanations around the outcome of the character on the toboggan.

Another similar interaction occurred during the same lesson with the second class. After a student drew a path on the IWB the class was asked whether they thought the animated character would survive their journey down it or not. The path drawn by the student can be seen in figure 9. Students began shouting out what they thought would happen before being asked to speak one at a time so that everyone could listen and be able to respond.
The following dialogue took place between two students:

**Teacher:** “What do you think is going to happen?”

**Student 3:** “I don’t think it’s going to go over the big hill.”

**Teacher:** “You don’t think it’s going to go over this hill?” (pointing to the second peak)

**Student 3:** “No the first one.”

**Teacher:** “What do others think?”

**Student 4:** “I say it’s going to go over the first hill.”

**Teacher:** “Why?”

**Student 4:** “Because it’s like going up…”

**Student 5:** “It has no momentum.”

**Student 4:** “Yeah thanks, it has no momentum to start off with.”

**Student 6:** (the creator of the line) “Yes it does, right here.”
   (Pointing to the first downward sloped portion of the line)
**Student 7:** “Yeah but you can’t get there.”

**Student 4:** “You need momentum to start off with.”

This episode was initiated by the drawing of a pathway on the IWB and the students’ ability to visualize what was about to happen based on their knowledge of slopes as well as previous pathways that they had seen other classmates draw before this one.

The first student to speak initiated the idea that the character would not be able to even begin as the path began on an upward sloping hill, although she was not able to articulate this as the reason. The second student then came in and put forth the notion of beginning on an upward slope while another student assisted him in his explanation with the idea of momentum.

*Figure 10  Student drawn path in LineRider*

[Image: Screen shot of path drawn by student]
It was then interesting that the student who drew the line was attempting to point out that the momentum would happen on the downward portion without realizing that it would be impossible to get to that portion of the path until another student explicitly stated that ‘you have to get there first’.

This episode within the lesson resulted in a lot of student-to-student dialogue. The role that the teacher took in this episode was to only ask one or two clarifying questions so that the whole class was clear on what was being articulated. It was also interesting because students were responding directly to one another. Students are not just throwing out ideas, but are actually responding to each other’s ideas and comments. This is the type of student-to-student interaction that was anticipated from this study.

As the lesson progressed students began to take the concept of slope further. They had created enough paths similar to the previous image to be able to hypothesize fairly well if the animated character would crash or not. Now they wanted to explore more complex paths. Although this was not within the scope of the learning outcomes it was an important episode as the class as a whole were wanting to go further and explore more complex issues, albeit, in a fun environment. The idea of what would happen if loops were drawn in the path became the focus of the class and the first student to attempt a loop drew the path seen in figure 11. Before drawing the path he asked; ‘Can I draw a circle or something?’ to which I replied that he might try if he wishes.
There were two points of discussion to the path drawn by the student. The first dealt with the loop that the student drew. There was a discussion around whether students felt that the character would fall off of the path at the loop and how come.

**Teacher:** “What do you think is going to happen?”
**Student 1:** “He’s going to fall off?”
**Student 2:** “He’s not going to get up the first hill.”
**Student 3:** “He’s going to go off that one.” (pointing to some unknown part of the path)

**Teacher:** “Why is he going to fall off?”
**Student 1:** “Because….”

note: - the first loop was inverted
Student 3: “He’s not going to fall off because they connect right there.” (the student can be seen pointing to the area indicated by the arrow where the two lines cross)

Student 4: “He’s going to flip and die.”

In the end the second student was correct and the character did not get over the first peak. This was not the same class that had the previous discussion around momentum and needing enough speed to make it over the first hill, so this was the first time they had encountered this scenario.

As the first path did not work because the character could not get over the first peak, the same student then drew a second path. In his second diagram (figure 12) the student drew the loop in the other direction so that the character would be travelling on the inside of the loop compared to the outside of the loop in the previous diagram.
Before the class was able to watch the outcome of the path, the question was posed as to what was different between the two paths.

**Teacher:** “What did student 1 do differently than he did last time?”

**Student 4:** “He allowed for more speed”

**Student 6:** “The loop…”

**Student 3:** “The loop is different”

**Student 4:** “The lines cross under instead of over.”

At the same time that students are shouting out their answers it is also possible to see a number of students pointing at the IWB as well as one student who make hand gestures in the form of loops. She makes two distinct gestures, the first demonstrating the second loop which is the traditional type of loop that is seen for paths where the character travels on the inside of the loop (her hand is
rotating counter-clockwise). Her second gesture demonstrates the loop in the first episode where the character would travel on the outside of the loop (her hand travels clockwise).

We then went on to test the two different possible methods for drawing the loop with respect to the program. We first tested the second path drawn by the student. As predicted, the character went around the loop. I then redrew an example of the first loop (figure 13) to test the student’s original thought and as predicted by one of the students in the first episode, because the two lines crossed, the character skipped over the loop. Although this is different than what would happen if this were a real track, the student who had originally predicted this outcome either did not understand that in reality the lines don’t actually cross, or else he was able to recognize the path in the context of the software program to understand that when these two lines cross the character could not attempt the loop. It would have been beneficial to clarify this with the student at the time; however, I did not do so as I most likely overlooked the first comment by the student moments earlier.
This episode provided some thoughtful discussion amongst students and enabled them to examine aspects of slope that were not an intended part of the lesson. The dialogue between the students provided both the student at the IWB and others involved in the discussion with feedback and opinions on what was taking place. These types of discussions, although not rich in mathematical content in this case, provide a forum in which students can share ideas, learn from each other, and test hypotheses instantly using the IWB. The IWB assisted in creating and facilitating this discussion by providing a public forum for students to create and discuss their ideas. The ability for students to witness their classmates create a path allowed for instant feedback and, perhaps more
importantly, provided the context in which they were able to link the actions required for each particular outcome. The IWB is a key piece to this episode as it allows for the line to be drawn and tested by the student. Although students could draw similar lines on a blackboard, they would not elicit the same participation from students as they could not be tested in the way they were with the IWB.

4.3.4. **Examples of Non Participation**

Up until this point in the analysis all of the episodes presented are done so as a way to exemplify the IWB’s ability to elicit participation within the mathematics classroom. Each episode has been used to assist in addressing my research question presented at the beginning of this thesis. However, while carrying out this research study it became evident that answering my research question was going to be much more difficult than I had previously anticipated. After collecting and analyzing approximately 12 hours of video, the number of episodes that did not succeed in eliciting the type of participation that I had anticipated was quite high. It was not anticipated that every moment of each lesson would demonstrate the effectiveness of the IWB, however, it had equally not been anticipated that so much of the time during the lesson would fail to occasion the type of participation desired.

In this Section, I report on a number of such episodes with the goal of trying to better understand the kinds of barriers that might arise—in terms of promoting a participatory classroom—in the use of IWBs. Each episode is meant
to highlight a particular problem encountered in this research study. Chapter 5 will focus on why these episodes may have occurred and what could be done in the future in order to minimize their occurrences.

Perhaps the lesson where there was the least amount of participation as defined within this study was the fourth lesson that focused on creating algebraic expressions using a couple of online applets. The goal of the lesson was to have students explore algebraic expressions by using both physical and virtual manipulatives. Students first learned how to use manipulatives at their desks and were then introduced to the two applets that used virtual manipulatives. It was hoped that students would engage in discussion around the creation of various expressions and use the IWB as a focal point for presenting and testing their ideas.

Below is an exchange between the teacher and students when attempting to create expressions using the National Library of Virtual Manipulatives applet Algebra Balance Scales. I had displayed the equation on the IWB a couple of minutes prior and gave them time to work on it in pairs with their physical algebra tiles.

**Teacher:** “*Ok, who wants to come up and show me how you represent that?*”

[8 second pause]

**Teacher:** “*So this is one side and this is the other side of the equation.*” [pointing to each side of the applet where the appropriate tiles need to be placed – figure 14]
Teacher: “All you need to do is....these are our x tiles, you just…….”

[attempts to move an x tile to the left side of the equation, however, it doesn’t work.]

[spends 35 seconds before getting the program to respond]

Teacher: “Ok, all you have to do is double click on it and then drag it over. Who wants to come and show us how you represent 2x+3 = x + 6?”

[45 seconds pass as students’ talk amongst themselves and the teacher fiddles with the IWB]

Teacher: “So someone come up and do that for me please.”

[30 second pause]

Teacher: “Come on guys. Do I have to start picking people?”
[A student then volunteers and comes up to the IWB and completes the task. As the student is working at the IWB the class appears to be watching what she is doing at the IWB]

**Teacher:** “Ok, is this what you had on your desk?” [students had already been asked to model the expression using the manipulatives they had at their desks. The teacher then quickly reviews the answer and moves on to the next question]

In this episode, there was very little interaction from students. They were reluctant to participate, and they were not given any real opportunity to have a discussion, nor did the question lend itself well to any discussion. In fact, throughout the entire episode, the only person speaking was the teacher. There was very little student interaction and there were not any significant instances of participation that could be included in the previous sections, based on the characterisation of participation that I have been using. This, despite my prior expectation that the use of the applet in the context of this lesson would occasion participation. The reasons for this failure in participation will be explored in more depth in the next chapter.

In an episode from another taped lesson, once again, eliciting the manner of participation outlined for this study proved difficult—although not as difficult in the previous example. This occurred during the third lesson that focused on solving various word problems using students’ knowledge of circle geometry in conjunction with GSP and the IWB. The lesson was structured in a carousel format, whereby groups of students would rotate around the room stopping at six
different stations to solve a problem. One of the problems was to be solved using the IWB and GSP.

The first group to work at the IWB spent more time familiarizing themselves with the IWB than they spent working on the task. Students had difficulty working with the IWB so that there was only one contact point with the IWB at any time. Earlier model IWBs, like the type used in this study, only allow for one point of contact at any time. That means that two students cannot be simultaneously using the IWB. Students found this difficult in the beginning. They wanted to have more than one person using the IWB when trying to work collaboratively. Although some of the later model IWBs now allow for simultaneous contact, it is still limited as to how that can apply in a program such as GSP. The students in this situation also spent a lot of time writing and then erasing their work as their markings were not appearing as they would like. This was due to the board being slightly out of alignment at times as well as students not being accustomed to the amount of pressure they needed to apply to the IWB with the pen when writing. Finally, because the IWB was a portable model with a projector that was not ceiling mounted it was difficult for students to place themselves in such a way that they were not blocking the image being projected on to the screen. As other groups used the IWB throughout the lesson, many had similar experiences. All of these issues could have been minimized or eliminated had students had more experience working at the IWB.
At one point in the lesson when a student was attempting to draw on the IWB to illustrate the problem that has been posed, he encountered problems. As another student stepped in to assist him, the first student could be seen stepping back from the IWB and a few seconds later he stated; ‘the SmartBoard is retarded’. Two minutes later, when the teacher returned and began asking the group what they had done to attempt to solve the problem, the same student stated to the teacher ‘the SmartBoard hates me’. When students run into challenges with IWBs in the videos for this study they often step back or give up. This is often not seen with other technologies that students have more familiarity with and knowledge about. Students know how to troubleshoot when they are having difficulties and thus can work through these technological issues and continue with the task at hand. For instance, when students encounter problems while using personal computers, they can often troubleshoot most issues, as many of these students have grown up with personal computers in their daily lives. They use them on a frequent basis both at home and at school, providing them with the competencies to troubleshoot common problems. Students cannot approach IWBs in the same manner as the personal computer, smart phone, or iPad™. The only milieu that students experience the IWB in is in the classroom at school and in most cases only a few classrooms even have IWBs. Therefore, student exposure to them is minimal, and as there is only one board in each classroom, the amount of time they spend directly interacting with them is even less. Furthermore, generally speaking, students receive no formal training in
how they work, how to use them, and most importantly, how to troubleshoot or fix problems as they occur.

Overall, this lesson did not provide the results that were expected. Two groups spent more than half their time at the IWB trying to familiarize themselves with the technology or trouble shooting with the IWB. This effectively eliminated any flow that a group might be able to establish in working through the problem as well as frustrating students enough that they disengaged from the problem altogether.

Finally, even when students did approach the IWB the task that they were being asked to complete was interactive in the sense that they were using the IWB in order to answer a question; however, the task was one that did not generate much discussion. An example of this was when students were using the National Library of Virtual Manipulatives online applet Algebra Balance Scales. With this applet students were asked to represent various algebraic equations using a balance scale. Each side of the scale represented a side of the equation and students were asked to drag bricks and balloons on to each side to represent the equation. The bricks represented positive numbers and thus pushed the scale down, while a balloon was considered to be negative and thus pulled the scale up. Hence, if you were to attach a brick and balloon on the same side of the scale it would not move as they were the opposites of each other. Both bricks and balloons were available with a weight of one, or x.
When students were asked to represent an equation using the scale they proceeded to do so with relative ease. When they were finished, however, it was difficult to establish any sort of conversation with the class. We just moved on to the next question without any discussion. This is not to say that there was not a benefit to using the IWB and these particular applets in the lesson, however, their use did not elicit the participation structures that the study was looking for.

In order to further probe the lack of participation, I offer below an example of an episode in which my attempt to provoke discussion around the IWB failed. Figure 15 shows a screenshot of the applet showing the equation that a student had just attempted to represent using the applet.

*Figure 15  Screenshot of algebra balance scale*
Teacher: “So how do we know that we still haven’t got the correct solution? How do I know by looking at the diagram that this is not correct?”

Student: “Because the scale is tilted.”

Teacher: “Right, because the scale is tilted? And what does an equal sign mean?”

Student 2: “That both sides are equal.”

Teacher: “Right, so the scale should be balanced. So we know that one of these sides is not correct.”

As can be seen from the transcript there was little to no participation, as defined in this study, taking place: there were no uses of gesture, no use of the kind of dynamic language associated with the visualisation, and no interaction between students. My questioning was taking the form of IRE. All that was required was for a student to complete a simple task. The IWB was being used in what Clark-Jeavons would classify as being medium interactivity. Although the IWB is being used in an interactive manner, it does not advance a student’s knowledge of the concept. It is merely being used to illustrate a concept but not to build one’s knowledge base or understanding of a concept. This was not the intention of the lesson, however, it became evident that the applets chosen for this lesson did not contribute to enabling students to advance their learning significantly or to truly explore the concept being taught. It also reinforced the importance of open ended questions that allow can generate discussions and not just quick responses. Both of these issues will be addressed in the next chapter in more depth.
5. Reflections

The primary research objective for this study was to determine in what ways IWBs could elicit participation and engagement amongst students in a mathematics classroom. Chapter 4 highlighted a number of episodes where the IWB was instrumental in eliciting participation. Chapter 4 also highlighted episodes where the desired level of participation was not reached. This chapter will discuss the various reasons that led to the participation structures presented in the previous chapter as well as some of the factors that led to the challenges in eliciting participation in some of the lessons. Finally, some reflections on the study as a whole and the key findings and insights that have resulted from it will be presented.

Throughout this study, the goal was to examine the participation structures that are created in the mathematics classroom through the use of IWBs. Although there were numerous moments over the six lessons where it appeared that such participation was occurring, it was not to the extent that was expected and, as such, I have tried to better understand the reasons why. Sometimes negative results can provide as much insight as positive ones. In addition, I will also consider the reasons for the successes outlined in the previous chapter. Finally, I will discuss the challenges that arose in attaining the study’s goal.
5.1. **Successes**

As presented in the previous chapter, there were instances where it appears that the IWB played a significant role in the creation of participation structures within the classroom. These achievements provide some insight into what is required to build upon these successes to create more sustained and prolonged periods of student participation in the mathematics classroom. What factors led to these episodes? What are some of the general requirements needed to consider when planning for such episodes? This Section will attempt to answer these questions. Three key factors, which emerged from my analysis and interpretation of the data in Chapter 4, are discussed within this Section; the selection of appropriate activities, the proficiency of students in using the IWB, and the benefits to students provided through the use of IWBs in the mathematics classroom.

5.1.1. **Selection of Activities**

Although Hegedus and Penuel’s study (2008) focused on the technology used to create an environment that generated rich class discussions, the activity that they chose to demonstrate this is equally important. The ability to simultaneously display each student’s work on the screen enabled students to scrutinize each others work which led to some interesting discussions between students on how they determined which representations were correct and which were incorrect. The activity itself allowed students to quickly identify incorrect responses as the graphical representation would follow a clear pattern if correct.
The choice of this activity not only exploited the functions of the technology, but also enabled students to quickly identify mistakes and provide corrective feedback to one another. Such dialogue may not have taken place with the same technology but a different activity. It was anticipated that the activities for this study would encourage similar participation structures amongst students.

When planning the lessons for this research study my intention was to pick activities that would be interactive and that would have students approaching the IWB as much as possible. I believe that all of the activities enabled students to approach the IWB on a regular basis, however, the aspect that I perhaps did not think about enough was whether such activities could generate thoughtful discussion that would advance student’s learning and/or knowledge of a concept.

One activity that was successful in creating a participatory environment was the Line Rider activity. Students were able to provide their hypothesis on what they thought would happen or they could provide an evaluation as to why the rider did or did not crash. They could also offer advice to the student as they were drawing the path their character was about to follow. In essence, they could be involved in each step of the process whether they were at the board or not. Despite only one student being at the IWB at any given time, the entire class was able to participate and ideas were generated based on the fact that the activity was open ended. There were numerous paths that could lead to success as well as to failure and varied opinions as to why a path was successful or not.
Another activity that was successful in creating a participatory environment was the lesson that involved a carousel approach to learning. Students were given the opportunity to work in small groups and solve problems together. The problems were of a difficulty level such that students needed to work together and share ideas in order to solve the problem. The questions were at a level that they could be solved as a group, however, would prove challenging on an individual level. This meant that students needed to share ideas, discuss their thoughts and explain their rationale to one another resulting in the type of participation originally sought.

The use of GSP in the first 3 lessons provided students with a dynamic representation of circle properties and the physical actions required to manipulate circles and angles. This resulted in students being equipped with the ability to visualize the answer to a question or problem and to use gestures in their explanations to help facilitate participation levels. As gestures can assist students in explaining ideas and concepts that they are not able to explain on a strictly verbal basis, these activities were also instrumental in creating participation structures.

There were numerous successes in the types of activities that were selected, however, it would be inaccurate to portray every activity used in this study as being well chosen and which elicited the type of participation sought. The interactivity that I was seeking isn’t only about having students use the IWB, it’s how their use can engage and involve all students in the actions that are
taking place and in the results of those actions. The activity needs to be structured so that all students can participate in a meaningful way if they so choose. It is not that these activities were wrong; however, considering that the goal of each lesson was to create participation structures in a mathematics classroom, some activities were not suitable.

For example, when using the point plotter tool as a beginning exercise in the fifth taped lesson, students needed to use the IWB to successfully plot a point. The exercise was designed to review the concept of plotting of points, as it was not a large focus of their previous math course, and to prepare them for the remainder of the lesson on creating linear relationships. Upon analyzing the video, however, there was very little discussion that took place. It was not difficult to understand why either. After plotting a couple of points, there was very little to say by either myself, as the teacher, or the students, who were watching a classmate complete the task. Even when a student made a mistake, at most they were corrected and then the class moved on to the next task at hand. It would have been very difficult to have a meaningful discussion from the point plotter activity. The activity was arbitrary in nature. This is in contrast to the Line Rider activity that also included mistakes amongst students. The difference, however, was that the point plotter activity did not provide open-ended problems and/or questions. There was one correct answer and after getting it we moved on. In the line rider activity, there could be many ideas generated from one
event. Each of those ideas could then be justified by the students who generated them, and debated by others.

Within this research study, there were examples of both success and failure in this regard. The successes have resulted in identifying the common characteristics of such activities in an effort to seek similar properties in future activities. The failures have been equally important in that it was possible to compare and contrast the successful and unsuccessful activities to identify the difference between the two so that future activities include the successful characteristics while avoiding the unsuccessful ones. This was an important realization as all of the activities chosen had many similarities. All of the lessons incorporated the IWB, enabled students to interact directly with it, and included questions for students to respond to. The important aspect was to examine what was different between the two types of activities. I believe that I have a much better understanding of how to incorporate activities that result in a participatory classroom environment in the future.

5.1.2. Student Proficiency in IWB Use

Perhaps one of the most important factors in eliciting participation and student engagement was by attempting to have students as knowledgeable and proficient as the teacher in the use of the IWB. As mentioned in Chapter 2 the IWB is 'owned' by teachers first and foremost. The term owned is used to reflect the power imbalance between the teacher and student when it comes to IWBs. No other piece of technology used in the mathematics classroom has this same
relationship. Due to the size, cost, and purpose of IWBs, students will almost never use one outside of school. This is unlike the personal computer, the calculator, and many software programs whereby students and teachers for the most part have rather similar access. In addition, many teachers receive specialized training for the use of IWBs that is not directly provided to the students and often it is not provided in an indirect manner either.

Although students did receive a brief overview and had the opportunity to work with the IWB before the study took place, their training was still very limited. The school had only recently purchased these IWBs and only one teacher (myself) had any formal training in their use. I was the only teacher in the school who was using the IWB on a consistent basis. Despite the effort to provide as much exposure as possible before the study, it was still insufficient, as students had only begun the course five weeks prior to the beginning of the study.

Many researchers (Glover, et al., 2007; Clark-Jeavons, 2005; Slay, et al., 2008) identify the need for professional development for teachers to effectively incorporate the use of IWBs in the mathematics classroom. As previously mentioned, the school in this study had purchased 2 portable IWBs two years prior to the study, however, none of the teachers had been trained in their use or potential. Prior to my arrival at the school, the IWBs had never been used due to this lack of knowledge in their operation and use. I had previously worked at a secondary school that had a partnership with a leading manufacturer of IWBs that resulted in formal training being provided to interested teachers. In addition,
I also attended a level two workshop in Vancouver after arriving at the school where the study took place. Attendance at this workshop was at my request to further improve their skills and not at the request of the school or the district.

The lack of knowledge around the use and operation of IWBs resulted in them being under utilized in the school. Without my prior training I would have found it even more difficult than I already did in designing interactive lessons that attempted to exploit the full potential of IWBs in mathematics. There was little support from the district and the technology facilitator at the school did not have any experience using or trouble shooting with IWBs. This lack of support can have a significant impact on how IWBs are incorporated into the classroom. Without adequate training, it would have been very difficult to complete this study and the lack of support was felt when there were technological glitches or when I had specific questions around their functionality.

In the first few lessons many students were apprehensive to approach the IWB. In many cases, they were willing to verbally answer a question that I posed, however, when asked to illustrate their thoughts on the IWB they either hesitated or decided not to continue. In the first lesson on inscribed angles such an episode occurred. The class was investigating the relationship between inscribed and central angles that share the same endpoints. A student had just been at the board to demonstrate the relationship and a student noticed that one angle was acute while the other angle was obtuse. The following is a transcript of what happened next;


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Teacher: “So in this case one angle is obtuse and one is acute. Does this always have to be the case?”

Student 1: “No.”
Student 2: “No.”

(the two students answered simultaneously)

Teacher: “No Student 2?”

(the teacher tells the student presently at the IWB that they may sit down)

Teacher: “Student 2, come on up and show us a case where one is not going to be acute and the other obtuse.”

Student 2: “I don’t want to.”
Teacher: “Come on. Let’s just try, right?”

(the student reluctantly approaches the IWB)

Teacher: “Let’s help student two out here. How can he change the angles here? How can he do that?”

(the activity carries on with the class assisting the student at the IWB)

There were numerous other episodes throughout the taped lessons that were similar to this. Students needed coaching and encouragement to come up to the IWB. Their initial reaction was to resist having to use the IWB in front of their peers. Despite the ability to quickly erase work or change any mistakes, students were apprehensive to display their work on the IWB. Prior to beginning this study I had not anticipated this. I had envisioned the IWB as having less permanence than the blackboard due to the ability to quickly erase or undo an action. It appears as though students may look at the IWB as having greater permanence. Perhaps knowing that although an action can be quickly undone with the IWB it is also not permanently gone. Students’ work can be brought up after erasing it by using the redo function of most software programs. As most
students are aware of these functions through their familiarity with personal computers, they may see their work on the IWB as being more permanent than the blackboard where once work is erased it has been erased permanently. Having students publicly present their work can be a challenge in the mathematics classroom at any time, and it seemed to prevail even when using the IWB in this study. Over the first few lessons only the same small subset of students were willing to use the board. Part of this could be attributed to the fact that students were aware that the cameras were recording and did not want to be ‘wrong’ on tape; however, the same situation arose during lessons when the camera was turned off.

It was interesting to note that after a student did publicly use the IWB, their hesitation seemed to disappear. During the circle geometry lessons (the first three lessons of the study) when a particular student first approached the IWB she was nervous in using it. As the student touched the IWB to move the vertex of an angle, she inadvertently drew a line. When this happened she jumped back, and turned her head away almost as if she had received a shock from the IWB. At this point the student and the class laughed. The images in figure 16 show this sequence. Later in the lesson, however, the student volunteered to approach the IWB again and her confidence seemed to be greater. As the study went on this student continued to volunteer to approach the board in each successive lesson.
Figure 16  Student’s reaction to an unexpected line being drawn
Another student demonstrated the same increased confidence in her use of the IWB. Although she did not have the same initial experience or reaction to the IWB, she was somewhat hesitant in using it for the first time during the first taped lesson. She quickly became comfortable with its use and subsequently raised her hand numerous times per lesson to approach the IWB. At one point I had to speak with her to thank her for the contributions she was making and explain to the class that I was also looking for others to volunteer. Her increased familiarity with the IWB and other students’ hesitation created a dynamic whereby only a select few students were willing to use it in front of the whole class. This led to me asking students to approach the IWB in the first two lessons even if they did not have their hands up. This was done in order to ensure that in future classes more students would be comfortable using the IWB in an attempt to encourage whole class participation.

There were exceptions to such widespread hesitation. Two such cases were when students were working in small groups and when we used the online program, Line Rider. In both of these situations, being ‘wrong’ was more acceptable. In the case of small groups, it appears as though students were willing to take more risks when only a handful of students are watching. When using Line Rider, being ‘wrong’ meant that your character crashed, which was common for most attempts and which attracted good-natured laughter about the situation. It appears that the initial use of the IWB by students in front of the whole class was perceived as taking a risk that many were not willing to take at
that time. Their answer would be public, and although the same can be said for
the blackboard (the same issue exists for it as well) the IWB displays their work
in a bold and bright environment and had at this point a captive audience. This is
an important aspect because the IWB creates such a public forum. The fact that
a student’s work is up on the screen for all to see can create a sense of
reluctance to approach the IWB as they are nervous of being incorrect. Activities
that allow students to make mistakes without the fear of embarrassment are
important, especially in the first few lessons with the IWB. A wrong response can
result in embarrassment of the student depending on the reactions of their
classmates, which in turn may result in the student not wanting to approach the
board in the future. If students are not willing to approach the IWB then it
becomes a less effective tool in the classroom.

Although beyond the scope of this particular study, it would be interesting
to explore this aspect further to see if students became more comfortable in
approaching the IWB as time went on and they became more familiar with the
technology.

5.1.3. Linking actions using IWBs to understanding mathematics

Historically, mathematics education has largely been told and not
discovered. Much like the circle geometry unit used to be taught, students would
be told a number of concepts and perhaps given some static diagrams to study
or memorize. Although there have always been some teachers who have
attempted to break this mold, they have been few and far between. Recently
with the increased use of technology there has been a shift in this approach and
students and teachers are being encouraged to learn and teach mathematics
through exploration and discovery. The IWB, along with the accompanying
mathematical software provide a new avenue for students to discover and learn
mathematics.

An example of this could be seen in the first two lessons on circle
gometry and the lesson on linear relationships using the Line Rider program. In
the circle geometry lessons, the combination of GSP and the IWB allowed
students to explore various angle properties in a dynamic nature. As discussed
in Chapter 4, there were numerous examples of gestures used by students that
indicated the use of the IWB help facilitate their learning. The gestures used in
explaining concepts and providing justifications to answers resembled those
used to control GSP on the IWB. The ability for students to observe these
actions by others as well as use GSP themselves provided them with the
movements necessary to assist in their verbal explanations where they would not
have been able to express their thoughts, or would have had much more difficulty
doing so, without them.

With the Line Rider program, the ability to draw the lines, test them, and
discuss the results provided students with a different understanding of linear
relationships than if they had just looked at various static diagrams. The ability to
do all three (draw, test, and discuss) in real time resulted in rich discussions and
it is hoped that they finished the lesson with a much better understanding of slopes and lines than when they entered. The activity was also successful in having numerous students approach the board to test their ideas and engaging students. This was the only lesson of the study where it was never an issue to have students come to the IWB. In fact, there was not enough time for everyone who wanted to test his or her idea to do so.

One of the key findings from this study is the importance of lesson design and activity selection to elicit student-to-student dialogue. In many of the lessons in this study the activity was thought to lend itself well to the use of the IWB however, the missing portion to the lesson was student engagement. It is not enough to only select an activity that suits the IWB, but it also must suit the students and allow them to buy in to the activity and actively participate. It is important for students to feel a sense of ownership and control over the activity in order to truly create this dynamic of student to student dialogue where the teacher acts as less of an expert and more of a mediator and guide to the discussion. Throughout the six lessons that were taped the lesson using the program ‘line rider’ was the only episode whereby this student-to-student dialogue happened frequently. In the other five lessons, the dialogue was mostly student-teacher-student based. In addition to the design of the activity though, I discovered that I also needed to step back, as a teacher, in order to allow students to guide and control the discussion. This idea is explored in more depth in the next Section.
In addition, the type of software that is employed in a lesson seems to impact the style of participation that is present. For example, the three lessons on circle geometry elicited numerous episodes that included gestures, while the three lessons on linear relationships did not, while the three lessons on linear relationships seemed to create numerous episodes of student-to-student dialogue that the circle properties lessons did not. This appears to be a result of the software programs utilized in the lessons. The circle geometry lessons used GSP5 almost exclusively. This software is very visual in both the way students interact with it on the IWB as well as the resulting images that are created. This in turn resulted in numerous students using gestures that mimicked the manipulation of circles and angles while they were speaking. The lessons on linear relationships used software programs that facilitated discussions between students based the outcomes, however the programs did not involve rotating, sliding, or other manipulations of shapes thus reducing the quantity of gestures used in explanations.

5.2. Challenges to Participation

The research study as part of this thesis did not produce the intended results that were set out in the beginning. It was anticipated that this study would produce six lessons rich with episodes of participation that were facilitated through the use of the IWB and appropriate software. Upon analyzing the videos, however, there were far fewer episodes of participation as defined for this study than anticipated. This Section sets out to discuss this result as well as to
provide some possible explanations for this. Although not a comprehensive list, the aspects listed in this Section are thought to be the primary reasons for the lack of participation as it pertains to the IWB in this study.

5.2.1. Technological Glitches and Student Engagement

During this study the IWB that was being used was a portable device. This required that the IWB be connected to a laptop and that the laptop be connected to an LCD projector that was also mobile and placed on a cart. This created a web of wires as well as the potential for numerous glitches. As the LCD projector was not mounted on the ceiling it was common for students to knock the projector while walking by and thus knocking it out of alignment with the IWB. There were also other software glitches that periodically occurred. All of these can be expected given the setup in the classroom as well as the fact that technology will not always work when we need it. However, what was interesting in watching these episodes was how quickly such an occurrence could disengage students from the lesson and how difficult it was to get them back.

As one camera was always focused upon the students in the class, it became evident that within a few seconds of needing to attend to a technological issue, students had completely disengaged from the activity and begun talking to their classmates about other topics. When the issue at hand was resolved, even if it only took a minute to do so, it was difficult for students to re-engage in the lesson. It was surprising to see the amount of downtime in a lesson due to the need to attend to technological issues and then attempting to get students to re-
engage with the lesson. In one particular lesson over 10 percent of the time was spent on this and another lesson that was to be taped had to be abandoned due to the IWB continually malfunctioning.

Other examples of student frustration with the technology arose in the third lesson, where students were working in a carousel format. As students were grouped together and rotating around the room, the teacher was not always present at the IWB station as it was necessary to check in with some of the other stations to answer questions and guide students. At various points throughout the lesson students can be heard commenting on the difficulties they are having with the IWB.

The first group to work at the IWB spent more time familiarizing themselves with the IWB than they spent working on the task. Students had difficulty working with the IWB so that there was only one contact point with the IWB at any time. They wanted to have more than one person using the IWB at one time. They also spent a lot of time writing and then erasing their work as their markings were not appearing as they would like due to the fact that they were not applying enough pressure on the board for all of their markings to appear. Finally, because the IWB was a portable model with a projector that was not ceiling mounted, it was difficult for students to place themselves in such a way that they were not blocking the image being projected on to the screen. As other groups used the IWB throughout the lesson, many had similar experiences.
All of these issues could have been minimized or eliminated had students had more experience working at the IWB.

In Chapter 4, an episode was described where a student had become frustrated with the IWB and had stated that the IWB hated him. As the student did not have the knowledge and proficiency to troubleshoot the problem, he stepped back from the activity instead. This is often not seen with other technologies as students have more familiarity with and knowledge about them. Students know how to troubleshoot when they are having difficulties and thus can work through these technological issues and continue with the task at hand. Students cannot approach IWBs in the same manner as the personal computer, smart phone, or iPad. The only milieu that students experience the IWB is in the classroom at school and in most cases only a few classes even have IWBs. Therefore, student exposure to them is minimal, and as there is only one board in each classroom, the amount of time they spend directly interacting with them is even less. Furthermore, generally speaking, students' receive no formal training in how they work, how to use them, and most importantly, how to troubleshoot or fix problems as they occur; therefore, when problems do occur they easily become frustrated because of their inability to troubleshoot these issues.

If we want students to be able to proficient users of IWBs and embrace them in classrooms then perhaps this is an area that needs more attention. At the most basic level students can learn from the teachers who use IWBs frequently in their classrooms. Other possibilities could be at a department level,
if the whole department uses IWBs or at a school level if the goal of the school is to incorporate IWBs school wide. There is a benefit to having students proficient in their use and thus the time that would need to be spent at the beginning of the course, and throughout the year would most likely not take away from covering curriculum if it decreases the amount of time that students disengage from the technology such as in the example of the student who stepped back and did not use the IWB for the rest of the time that the group was at that station.

This idea is no different than with most other technologies in schools, however, it has not seemed to resonate within many schools. From a young age, students are taught how to use computers in school, and as each new piece of software is introduced, students receive some training on how to use it effectively in an educational setting. This could be because many educators still see the IWB as being their own, and not the student’s or perhaps they are not comfortable enough with the technology themselves to provide students’ with the training.

Increasing student engagement is often stated as one of the primary benefits of IWB use in mathematics classrooms (Thompson & Flecknoe, 2003; Slay, et al., 2008; Torf & Tirotta, 2009). When everything is working as it is expected this can definitely be the case as was evident in the introductory lesson on slopes using the line rider program. However, there is a need to ensure that the school and the school district adequately support the technology. The possibility of lost time during lessons as well as students disengaging from the
lesson when the technology does not work properly takes time away from their learning. Although it is impossible to avoid all technological glitches, ensuring that there is adequate support to both teachers and students can minimize the risk of interruptions.

5.2.2. Lesson Design and Interactivity

A common theme within the literature around IWBs in general and in mathematics classrooms specifically is the importance of appropriately integrating IWBs into the classroom—as I discussed in Chapter 2. Clark-Jeavons (2005) identifies three levels of interactivity when using IWBs in mathematics classrooms: low, medium, and high-interactivity. My goal was to attempt to design lessons that fit into the third category as I anticipated that the more interactive the activity, the more discussion and participation that could be generated from it. A highly interactive activity, according to Clark-Jeavons, is one in which students are able to interact with dynamic geometric constructions by dragging them into different configurations. In essence, students are able to engage with the software in ways in which they are unable to do so in a whole class setting without an IWB. It was these types of activities that were originally sought to elicit participation from students. Although highly interactive activities do not guarantee participation structures as those identified in this study, they can be closely linked. For that reason, each lesson was evaluated using Clark-Jeavons levels.
Through the analysis of the video for all six lessons it was possible to see each of these levels in the various lessons. Although the goal was to create high-interactivity lessons, the result was not always so. Lesson Five used online algebra tiles to teach students how to solve simple algebraic equations. The lesson was in the low-interactivity spectrum since using the IWB provided no benefit compared to what could be achieved using only a computer and LCD projector. The ability to physically move the manipulatives was not capitalized upon in the design of the lesson. Had the lesson been structured differently, perhaps this would not have been the case.

On the opposite end of the spectrum, the lesson focusing on the introduction of the concept of slope using the online application Line Rider as well as the first circle geometry lesson could be classified in the high-interactivity category. In the line rider lesson students were able to interact directly with the IWB in a manner that allowed them to convey their understanding of slope and also allow others to provide feedback both before and after witnessing the result of the path they drew. In this lesson students were eager to approach the board, offered opinions and advice in relation to another student’s ideas that was created and projected on the IWB.

The first circle geometry lesson had students dragging vertices of angles within a circle, creating cyclic quadrilaterals and dragging their vertices as well as dragging the endpoints of inscribed and central angles to determine the relationship between the two. This lesson was what could be classified as
having high interactivity, as students were able to manipulate and drag the various angles to discover the properties of inscribed and central angles as well as cyclic quadrilaterals. It is interesting that the majority of the episodes of participation in Chapter 4 came from these two lessons.

One of the key findings from this is study is the importance of lesson design and activity selection to elicit student-to-student dialogue. In many of the lessons in this study the activity was thought to lend itself well to the use of the IWB, however, the missing portion to the lesson was student buy in. It is not enough to only select an activity that suits the IWB, but it also must suit the students and allow them to take ownership of the activity and actively participate. Throughout the six lessons that were taped the lesson using the program ‘line rider’ was the only episode whereby this student-to-student dialogue happened frequently. In the other five lessons the dialogue was mostly student-teacher-student based. This also led to the discovery of the difficulty in stepping back as a teacher and allowing students to guide and control the discussion.

A considerable amount of planning and thought needs to take place in order for lessons to be classified in this upper level. In this study, initially it was surprising that more of the lessons did not achieve this level. However, upon further reflection and analysis of the literature as well as the videos, the differences between the various lessons have provided insight into why this was so. This has reinforced the need for careful planning to create and implement such lessons.
5.3. **Further Reflections**

5.3.1. **Student Engagement**

Throughout the taped lessons, students’ attention appears to be focussed on the IWB for most of the time it is being used. There is little off task behaviour, except when there were technical issues with the IWB as previously mentioned, which differs from the normal for these lessons. In British Columbia, all Grade 9 students are enrolled in the same class. Although there are many advantages to this, at times it can lead to considerable off-task performance or disengaging from the lesson due to many factors including; boredom because the lesson is not moving along quickly enough, not understanding because the lesson is moving too quickly, general disinterest in the lesson or subject, or a host of other reasons. This does not seem to be the case for the taped lessons involving the IWB. This level of attention continues when a classmate approaches the board to demonstrate an idea or answer a question. The videos show the vast majority of students paying attention throughout the lesson when the work is being presented on the IWB with a dynamic piece of software, whether it is a dynamic geometry program, online applets, or another interactive program.

The video tends to suggest that students are not just looking at what is happening on the IWB but also processing the content based on their responses to their classmate’s work on the IWB based on their responses to questions and the gestures they use in such responses. When the IWB is not used in a lesson, students easily tune out or ignore their classmates questions and comments, by
beginning their own side conversations with their seat mates. This does not appear to be as prevalent when the IWB is employed in the lesson. Whether this is because of the relative novelty of the IWB or due to an inherent advantage of IWBs in the classroom is not possible to ascertain, however, the difference is noticeable.

This observation is consistent with the findings of Miller and Glover (2001) who have also noted an increased level of engagement by students in mathematics classrooms with IWBs. Although it is hard to ascertain whether this increased level of engagement will translate into increased performance by students, it is a positive step forward in having students engaged and participatory in class.

This level of attention by students appears to be present regardless of the interactive nature of the lesson. Students appear to be more engaged from the perspective of paying attention to what is occurring on the IWB even during the more Socratic and less participatory lessons compared to classes where the use of an IWB is not employed even if that engagement is sometimes passive.

One caveat to this is the difficulty that I had in involving the whole class in discussions. Despite the perceived increase in the level of engagement, it was difficult to involve the whole class in discussions with the exception of the lesson on slopes mentioned above. The restriction of only one student being able to work at the IWB at one time definitely limited the amount of whole class involvement. The lesson on slopes was the one exception, however, it would be
difficult to incorporate activities such as this one in the majority of lessons. The Line Rider activity was ideal for the investigation that the class was exploring, however, when it comes time for students to practice their skills, the IWB proved difficult to involve the whole class. Having one student at the IWB and all other students watching is does not create an interactive environment where all students are actively engaged. In analysing the video from the six lessons it appears as though there is a significant difference between passive and active engagement of students.

The only consistent instances of students losing interest or disengaging from the lesson appear to occur when there are technological issues with the IWB or the setup.

5.3.2. Connected Classrooms

The idea of creating a connected classroom for this study came from Hegedus and Penuel’s work with SimCalc and graphing display calculators. From their work, much of the student-to-student discussion came from the ability of students to see each others’ work on one screen simultaneously. It was anticipated that the use of an IWB could also create similar conversations and participation structures. This, unfortunately, did not happen in my study. Although students were able to see the work of another as well as visually see the commands and actions that were needed to create the outcome, they were not actively involved in the process.
Connected classrooms require not only the primary piece of technology, which in this study is the IWB, but it also requires another piece or pieces of technology that allows all students to connect to the IWB so that many students can participate in the same task at one time as well as a task that effectively incorporates such technology. This was not possible in this particular study as the school and district did not have any of these technologies available. Although such technology does exist for IWBs such as clickers, wireless slates, and graphing display calculators, the district did not support nor did the individual school have the funds available for these additional pieces of technology. Despite this, the IWB did connect students by generating and facilitating numerous discussions that would have been difficult to create without the capabilities of the IWB and having it as the primary focal point in the lesson. Although this is not what is meant by a ‘connected classroom’ these personal connections and the ability to discuss mathematical ideas and concepts in an open format are invaluable to a subject that still struggles to actively engage its students.
6. Conclusion

Using the notion of participation structures as presented in the work of Hegedus and Peneul (2008), this thesis examined whether the use of IWB’s affect participation in mathematics classrooms. I videotaped 12 lessons between two Grade 9 mathematics classes in a suburban Vancouver secondary school to attempt to ascertain how, if at all, IWB’s could increase participation in my classroom. These lessons were then analyzed and relevant episodes were coded to identify the effect that IWB’s had in each lesson.

Overall, it appears as though the IWB can positively affect participation in the mathematics classroom through careful planning of activities and use of the IWB. There were episodes within the study where students seemed to use gestures to mimic the movements used on the IWB when explaining their thoughts. Some students were also able to better visualize the manipulation of geometrical shapes after having seen it modelled on the IWB using a dynamic geometry program and the use of various applets and programs. These episodes also resulted in rich discussions amongst students in understanding and explaining their mathematical thoughts and concepts. The inclusion of gestures and visualization in this study extends beyond the work of Hegedus and Peneul (2008), whose focus was primarily on student-student interactions.
As I began delivering and taping the lessons I realized that pursuing this question was not as straightforward as I had anticipated. The design phase of the lessons proved to be both more difficult and more important than I had previously thought. Two lessons delivered within this research study did not result in increased participation compared to the rest of the lessons in the study. This, coupled with the literature reviewed, suggests that IWB’s need to be a key aspect in the planning stage of lessons.

Limitations and challenges also presented themselves within this study. Students’ unfamiliarity with the technology as compared to other technologies used in the classroom posed a challenge, as did the aspect of using the IWB as more than just a digital blackboard. In addition, the literature suggests that the level of training that teachers’ have in the use and operation of IWBs affects their impact. These challenges that were encountered in my research seem to be surmountable with careful planning and training in the use of IWB’s in the classroom.

Overall, the use of IWB’s in mathematics classrooms appears to promote various forms of participation. Combined with dynamic software programs and online applets they provide students with new ways to create understanding through visualization, gestures, and class discussion. As IWB’s continue to become more prevalent in Canadian classrooms, it will be even more important to ensure that they are used in a manner that will benefit student learning.
References


