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HOW DOES THE USE OF STUDENT-CENTERED, INTERACTIVE TECHNOLOGY
IN THE SCIENCE CLASSROOM AFFECT STUDENT UNDERSTANDING OF
SCIENCE CONCEPTS?

by

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STATEMENT BY THE AUTHOR

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Emily Lindgren

The use of technology in the K-12 classroom is finally starting to catch up to the use of technology in society. In order for the use of technology to be an effective teaching and learning tool, it needs to be used properly. Interactive technology allows students to manipulate the technology as they learn therefore allowing each individual to create their own learning. Interactive technology needs to be immediately responsive, differentiated on its own, interesting and engaging to meet the needs of our techno-savvy students. In this paper, I examine three different forms of interactive technology for how they help students develop understanding of science concepts. I am researching the effectiveness of interactive whiteboards, interactive science simulations, and hand-held student response systems (clickers). Each form of interactive technology has the ability to engage students, but the research also shows that their effective use can also improve students understanding of science concepts.

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Chapter 1: Introduction

Over the past 30 years our society has advanced dramatically in the area of technology. Every aspect of life is overwhelmed with technology and schools are no exception. Unfortunately, society's technical advances are happening so quickly that schools are struggling to keep up.

Our students today are very different than those 30, 20 or even 5 years ago. Our students are growing up in an environment where they are constantly bombarded by stimulation through technology. Today's student has been raised in a world of instant information; a world where images and animations have replaced books and text, a world where video games and virtual worlds have stretched children's imagination instead of books and stories. They are used to a world where all answers are accessible with the click of a button. This has changed our students and the way they learn. "In contrast with the vivid images and self-directed flow of the interactive home and society, school strikes them as rigid, uninteresting, and ultimately alienating." (Strommen & Lincoln, 1992) This dissonance between school and home has created new issues in students' abilities to learn complex science concepts. As Marc Prensky noted in *Digital Natives, Digital Immigrants*, "our students have changed radically. Today's students are no longer the people our educational system was designed to teach" (Prensky, 2001). Prensky asserts that students today are qualitatively different from the generations that did not grow up with the Internet, MP3 players, video games and cell phones. Their thought processes are less linear, they demand instant access to information, and they are fluent in the digital media their teachers are still learning about (Prensky, 2001).

Statement of Problem

In an attempt to meet the ever-changing needs of our ever-changing students, the implementation of interactive technologies as teaching and learning tools are an important step towards reaching our students. This paper looks at how different forms of interactive technologies affect students understanding of science concepts.

Research Question

The question I will be investigating is “How does the use of student-centered, interactive technology in the science classroom affect students understanding of science concepts?” In investigation of this question, I will be breaking it down into three parts:

1. *How do interactive simulations affect student understanding of science concepts?*
2. *How do interactive white boards, when primarily used by students, affect student learning?*
3. *How do handheld student responses systems (clickers) affect student learning?*

Limitations and Assumptions

My research in this is limited due to the novelty of this topic. Much research has been done on how engaging interactive technology can be, but less has been done on its effectiveness on understanding especially on science concepts specifically. Much of the research found has been done by individual companies and is used to promote their products. The research is therefore biased and independent research is limited.

In doing this research, I am assuming that with changing times, education should change as well and we need to be accessing the ever-advancing technological world to reach the children of the 21st century.

Definition of Terms

Interactive Whiteboard (IWB) - An interactive whiteboard is a touch-sensitive screen that works in conjunction with a computer and a projector.

Interactive Simulation (sims) – animated, interactive computer based application that students can manipulate to observe and visualize concepts.

PhET – (Physics Educational Technology) Research-based simulations free for use by all and developed by Colorado University.

Multiple Intelligences – the theory that there are eight basic types of intelligence (Spatial, Linguistic, Logical, Kinesthetic, Musical, Interpersonal, Intrapersonal, and Naturalist) and a child can be more one type of intelligence than another.

Open Source Software – is a development method for software that harnesses the power of distributed peer review and transparency of process. The idea of open source is better quality, higher reliability, more flexibility, lower cost, and an end to predatory vendor lock-in.

Java – a high-level computer programming language used to create interactive applications

Flash Player– is a cross-platform browser-based application that delivers uncompromised viewing of expressive applications, content, and videos across screens and browsers

Bluetooth – a short range, radio technology for computers and mobile devices.

Wireless slate – a wireless tablet that communicates with a computer and mirrors the movement of a pen on the slate on the computers desktop. It can be used with or without an IWB.

Wii –video gaming system made by Nintendo. It has an infrared receiver.

Wii Remote – video gaming controller with an infrared sensor.

Chapter 2: Review of Literature

How do Interactive Simulations Affect Student Understanding of Science Concepts?

Research on how students learn shows that students learn better when they develop their own knowledge of scientific ideas while building on what they already know. To do this, students need to be driven to actively engage themselves with the content. Interactive computer simulations meet this need. (McKagen, Perkins, Dubson, Malley, Reid, LeMaster, & Wieman, 2008) Interactive computer simulations have shown great promise in helping students effectively develop scientific understandings with the use of modern technology. “Interactive simulations are a new way to convey scientific ideas and engage students in educational activities. The combination of advances in personal computer hardware, platform independent software such as Flash and Java, and the Internet provide tremendous new capabilities.” (Wieman, Adams, & Perkins, 2008)

The fundamental valuable characteristic that all these animations and simulations share is that, if written in a language such as Flash or Java, they can be run through a standard browser anywhere in the world. This capability provides exceptional flexibility in their educational use. They can be integrated into a lecture or laboratory, used by students in doing homework assignments, or used as an informal resource. (Wieman, Adams, & Perkins, 2008)

Using simulations, students can build understanding through somewhat guided exploration. These simulations allow students to explore, visualize processes, and interact with and manipulate the simulations in their own way, as they build understanding. Effective use of interactive simulations allows complex scientific topics

and concepts to be presented without difficult scientific language and mathematics, therefore making the science more accessible and understandable to previously unreachable and uninterested populations. (McKagan et al., 2008; Wieman, & Perkins, 2006)

Individual teachers have created their own simulations as technology has advanced, and many companies offer interactive simulations at a cost. Another group, through Colorado University, The Physics Education Technology (PhET) Project, creates free, research-based, interactive, educational simulations for students of all ages. These simulations are free and available to all on the PhET website (<http://phet.colorado.edu>). The PhET Project has over 80 interactive simulations that cover various topics in physics. There are also additional simulations on topics in chemistry, math, biology and earth science. “The simulations are animated, interactive, and game-like environments where students learn through exploration.” (McKagan et al., 2008) University of Colorado professors Carl E. Wieman and Katherine K. Perkins have been developing simulations and studying their effectiveness. “Our data indicate that well developed and tested interactive sims (simulations) can convey ideas in very different and more powerful ways than traditional educational media, and resonate with students who have grown up in a culture of internet and video-games.” (Wieman & Perkins, 2006) Wieman and Perkins believe that interactive simulations will soon take the place of many traditional demonstrations and labs, that often lead to more confusion than understanding, due to the simulations controlled environments and accessibility to all age levels. (McKagan et al., 2008, & Wieman & Perkins, 2006)

The PhET project has two primary goals for each simulation: increase student

engagement and improve learning. Most interactive technology addresses the same goal of increasing student engagement, but few are able to specifically claim that they can also improve student understanding. PhET simulations focus on real-world situations and applications. (McKagan et al., 2008)

“PhET simulations are highly interactive, directly coupling students' actions with the animation. Adjustment of controls results in an immediate animated response in the visual representations.” (McKagan et al., 2008) Through manipulation of the controls in each simulation, students are able to develop cause-effect relationships. Many simulations have multiple representations; therefore, students can develop different visual images of processes that are not usually visible to the human eye. PhET simulations are purposely designed to help students build in-depth conceptual understanding of the science concept through exploration. (McKagan et al., 2008) “One notable characteristic of these (PhET) simulations is that they blur the division between elementary and advanced material, so many high school teachers find simulations on “advanced” topics quite useful, and university faculty and students from first-year to graduate students find that introductory simulations can provide new insights.” (Wieman et al., 2008)

“Interactive simulations can be uniquely powerful educational tools. They must be carefully designed and tested and used in pedagogically effective ways. The results of our (The PhET Project) research on the testing and use of simulations matches closely with previous research on learning and effective educational practices.” (Wieman et al., 2008) The PhET Project takes great care in creating their simulations to ensure that they meet their goals of increasing student engagement and improving learning. A PhET simulation takes months to create and has 10,000 plus lines of code. The PhET Project

follows “The PhET Design Process” (Wieman et al., 2008) depicted below. Simulation design is based on research into student understanding on the exact content area that each simulation is intended to cover.

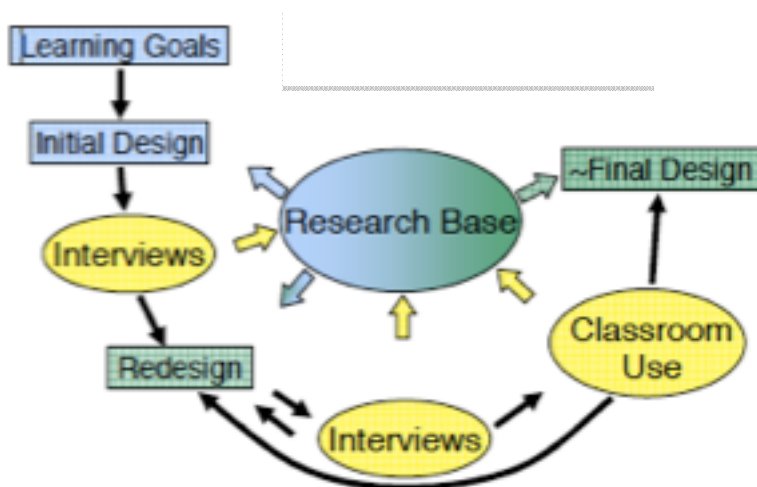


Figure 1. The design process of developing PhET simulations by Colorado University.

First a group of science teachers, educational experts and technical support people clearly define the learning goals of a specific simulation. Then they develop an initial design that is tested by students of all ages. The test students are then interviewed to see what they liked and didn't, what was easy to use, what was not, and whether the students met the learning objectives. Areas to improve are then identified and the simulation is redesigned. The simulation is then tested again and the test students are again interviewed. The entire process is based on educational, research-based practices. When the simulation meets the needs of the students, it is then made available to the public on the PhET website.

A simulation *per se* does not automatically, or even readily, come with great pedagogical power. In our hundreds of hours of testing them with students, we have found sims can easily be boring, frustrating or misleading. They can also be

fun and engaging, but educationally worthless. (Wieman & Perkins, 2006)

“Only by going through multiple test cycles with students, and modifying the sim in response, is it possible to be confident that students will have the same interpretation of what is happening in the sim as experts.” (Wieman & Perkins, 2006)

Each PhET simulation is carefully designed to help students build scientific knowledge regardless of their previous scientific experiences. Before a simulation is released to the public, it is tested and proven to be pedagogically effective when used properly.

A good simulation provides the student with the equivalent of training wheels on a bicycle, effectively substituting the constraints and display of the simulation for expertise. This support allows students to carry out exploration and learning that is cognitively similar to that of a scientist, something they do not have the experience or motivation to do with most real equipment in physics. With real equipment, the numerous complex unknowns are mysterious, uncontrollable, and threatening. (Wieman et al., 2008)

A well-designed simulation is found to be fun while helping students to explore new scientific ideas and focus the students' attention on the specific science concepts. “When something unexpected happens, the student questions her understanding and changes parameters in the simulation to explore and improve her understanding—approaches similar to those taken by a scientist working with an experiment.” (Wieman et al., 2008)

PhET simulations are designed with three important aspects to help students at different age levels and different levels of scientific competence learn from each simulation. These aspects are their ability to help students visualize processes, their built

in scaffolding, and their non-reliance on complex scientific language and mathematics. (McKagen et al., 2008; Wieman & Perkins, 2006; Wieman et al., 2008)

“Visualization and interactivity help students construct mental models. Putting physics in familiar real-world contexts helps students relate new concepts to prior knowledge.” (McKagen et al., 2008) The ability to manipulate the sims individually allows students to develop their own visual models and understanding. These simulations are vital in helping students visualize phenomena that are not possible to see with the human eye like atoms, and electromagnetic waves. The dynamic visual environments of these sims is also what make them as visually engaging as many video games. (McKagen et al., 2008; Wieman et al., 2008)

Each PhET simulation is designed to start at an introductory level, and build into a more advanced level of understanding all in one sim. An example of this is the “Radio Waves” simulation that models how electromagnetic waves travel (figure 2) and how electromagnetic fields act (figure 3).

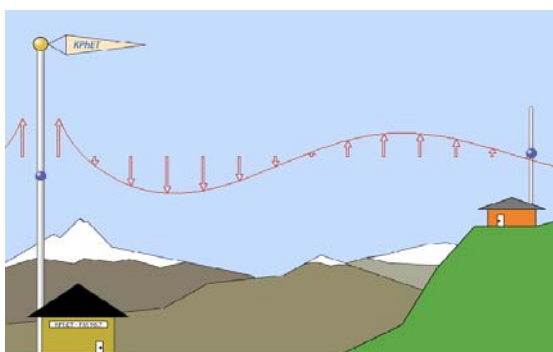


Figure 2. Introductory View of Radio waves in PhET Simulation.

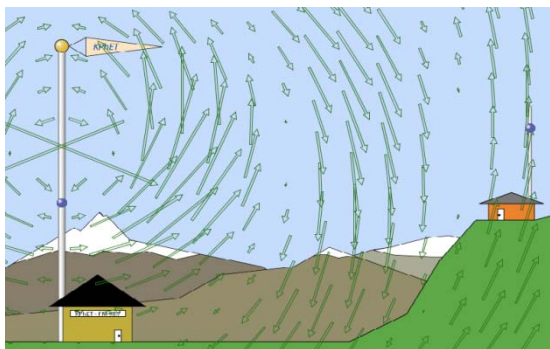


Figure 3. Advanced View of Radio Waves in PhET Simulation.

If students are introduced to the advanced view prior to the introductory view, they often find it very confusing and frustrating, but after the introductory view, students often prefer the advance view because it is more complete once they have the background to build on (Wieman et al., 2008).

PhET simulations are specifically designed to productively constrain students' focus on the aspects experts believe are most important. The design is tweaked—enhancing certain features, hiding others, adjusting time scales and so on—until the desired student perception is achieved. In this way, our simulations have an advantage over real-world demonstrations or labs, which typically include enormous amounts of peripheral, but unavoidable, information. (Wieman et al., 2008)

In a real world lab on circuits, students often pick out details like the color of a wire that they think may be a contributing variable, but in the PhET simulation, this is a detail that is constant, so students cannot identify it as a possible contributing variable. This then focuses student on what is important. (McKagen et al., 2008)

Another unique and vital aspect of PhET simulations is that they “reduce cognitive load by freeing the learner from the typical language barriers of highly

technical terminology that can often inhibit student understanding in the classroom.”

(Wieman et al., 2008) This helps students build their own understanding. When a simulation starts in an introductory level and builds, students then build their knowledge as they progress. These simulations also have the unique opportunity to make mathematics a non-issue, which makes the science concepts accessible for much younger students.

Many of the quantum simulations take advantage of the power of computers to quickly do complex calculations without exposing the user to the details. Thus, students can explore quantum tunneling and quantum wave interference qualitatively and focus on understanding the concepts without getting bogged down in the math. This has the potential to radically transform the way quantum mechanics is taught because it allows the instructor to focus on the problems that are most important for students to understand rather than on the problems that are easiest to calculate. (McKagen et al., 2008)

Besides mathematics and scientific language barriers, time is often a major barrier to real scientific exploration in the classroom. Interactive simulations have the ability to control time and have it pass quickly or slowly depending on the necessity. “Simulations provide a unique tool for exploring time dependence in a way that is impossible in print media, helping students to see how quantum phenomena evolve and change in time.” (McKagen et al., 2008)

Although the use of interactive simulations in the classroom is just taking off, The PhET Project is far ahead of many other producers of interactive simulations. Due to their research-based design, engaging, interactive features and free to use access, these

simulations will be apart of the science classroom for years to come. (Wieman et al., 2008)

How do interactive white boards, when primarily used by students, affect student learning?

An interactive whiteboard, or IWB, is a large touch-sensitive display that connects to a computer and projector. A projector projects the computer's desktop onto the board's surface, where users control the computer using a pen, finger or other device. The board is typically mounted to a wall or on a floor stand. Interactive whiteboards are used in many schools as replacements for traditional whiteboards, flipcharts, or video/media systems such as a DVD player and TV combinations. The IWB gives teachers the possibility to use still images, moving images, animations, and sound, video clips, text that can then be manipulated, and many other applications. (SMART Technologies, 2006)

Interactive whiteboards work through a USB, serial port, or a Bluetooth connection on the computer. The pen or finger then becomes the mouse and can move through aspects of a computer. IWB's allow the user to prepare material in advance or build it in front of a class, quickly retrieve it for display to the whole class when required, and manipulate items directly on the display in a way that corresponds to what can be achieved with an individual computer. Most interactive whiteboards come with software that helps the user develop lessons that are designed to be interactive and allow for notes to be taken at any time while still allowing for movement between web browsers and premade lessons. Teachers are able to move seamlessly and frequently between whole-

class, group and individual instruction, which makes the possibility of meeting the needs of each student more realistic. (Kennewell et al., 2007; Smith et al., 2005)

The use of interactive whiteboards differs in every classroom, but when used properly, they can have great impact on student learning. IWBs become the focus of the whole class for whole class lessons, discussions and activities. They also become a way for students to demonstrate solutions, show individual work or multiple solutions to problems. They can be used to demonstrate, visually, how to solve step-by-step problems. IWBs can be used to review concepts with the whole class, with small groups, or one on one. They work well in facilitating differentiation as one group can be working through a concept on the IWB while others who already understand a concept can be working individually or in groups. (SMART Technologies, 2007a)

Along with interactive whiteboards, most companies also offer wireless slates. A wireless slate is a handheld IWB. It has “an input surface that matches input points on a corresponding interactive whiteboard” (SMART Technologies Inc., 2007b) or just a computer desktop. When you move the pen over the slate, the movement is mirrored on the whiteboard as well as the computer desktop. One or more wireless slates can be used by both teachers and students and can be used with or without an IWB. Slates make it possible for students with limited mobility and students who are uncomfortable in front of the room, to participate from their seats. Wireless slates can be a good option for districts with budgets constraints since they do not need IWB to function, just a teacher computer. The slate is also a simpler option for small group and individual re-teaching, as students do not need to be in the front of the room. (SMART Technologies Inc., 2007b)

More and more companies are making interactive whiteboards. Some of the bigger name boards/companies are: SMART Boards, Promethean ActivBoards, Interwrite Boards, and Mimio. There are also more and more homemade versions that operate using a Wii remote. With all these different companies, there are really only a few different types of boards including resistive touch screens, electromagnetic, optical and infrared. (Tech & Learning, 2009)

Resistive touch screens, like SMART Boards, are made of two flexible sheets coated with a resistive material and separated by a very thin air gap. When contact is made to the surface of the touch screen, the two sheets are pressed together, registering the precise location of the touch. This technology allows one to use a finger, a stylus/pen, or any other pointing device on the surface of the board. Electromagnetic interactive whiteboards, like Promethean ActivBoards, have wires embedded behind the board surface that interact with a coil in the stylus tip to determine the (X, Y) coordinate of the stylus. Styli are either active (require a battery or wire back to the whiteboard) or passive (alter electrical signals produced by the board, but contain no power source). A Wii remote can act as an interactive whiteboard when connected to a computer through its Bluetooth connection capabilities. Using open source software and an infrared pen (a pen made with a momentary switch, power source and an infrared LED) any surface (desk/floor/wall/whiteboard/LCD) can be turned into an interactive whiteboard. The Wii remote has a very accurate infrared light-tracking camera. Once calibrated, the Wii remote detects a mouse click at the screen location of the IR-Pen. It is thought that this technology could revolutionize the interactive whiteboard craze with cheap versions

anyone can buy and make. (Gail Dean, personal communication, 2009; Tech & Learning, 2009 & Wikipedia, 2009)

Interactive whiteboards have been shown to be preferred over traditional instruction methods (lecture, videos, whiteboard/chalk board use, etc.) by both teachers and students (Smith, Higgins, Wall, & Miller, 2005). “I see the impact of (interactive) whiteboards in teacher collaboration, students engagement, real-time information (retrieval) and fluid lesson planning,” says Principal Gary Hein of Euclid Middle School, Littleton, Colorado, after having interactive whiteboard installed in every classroom for just over a year. (SMART Technologies Inc., 2007b)

According to the British Educational Communication and Technology Agency (*BECTA*) *Research Bulletin- Interactive whiteboards significantly affect teaching and learning* (2007), IWBs “enhanced the overall classroom experience” in many ways. Some of the primary effects are that IWBs increase student engagement in lessons, allow students to manipulate text before they have the writing skills that may be need with other mediums, they can boost student self-esteem while allowing teachers easier access to assessing student learning. The use of IWBs can also help to develop a sense of community through shared learning while allowing the teacher to be more mobile which can help to improve student’s behavior and meet the unique demands of students with special needs. (British Educational Communication and Technology Agency (*BECTA*), 2007)

Another major advantage to using interactive whiteboards is their ability to aid in teaching of abstract concepts and complex ideas. IWB’s allow teachers to represent abstract concepts in a visual manner so students have a visual representation to connect to

the abstract idea. This helps students both understand and remember what they have seen, heard and experienced. (SMART Technologies Inc., 2009; Knowlton, 2008)

Interactive whiteboards help teachers teach to the multiple intelligences and different learning styles of their students. Many students today are visual learners who learn best when information is being taught and supplemented with images, videos, animations, and diagrams. IWBs allow teachers to present new information in concrete ways like notes, but then also demonstrate this information with images and visual demonstrations. (SMART Technologies Inc., 2009, Knowlton, 2008)

“... Interactive whiteboards, when used with appropriate pedagogy and digital recourses, can lead to improved student learning outcomes and teachers’ quality of life.” (SMART Technology Inc., 2007b). Teachers have reported great benefits from the use of IWBs in the classroom beyond student engagement. Some benefits noted are teacher’s ability to assess students leaning quickly and seamlessly, preparation for lessons becomes easy after the learning curve with equipment, and using IWBs makes spontaneous teaching moments easy to accommodate with a few clicks of a mouse. (British Educational Communication and Technology Agency (*BECTA*), 2007)

Teachers have reported two other vital benefits from using IWB and the software that comes with the boards. These benefits are increased opportunity and fluidity of differentiation and collaboration/lesson sharing/ and reusability. Differentiation becomes easier because one group can be working through a preplanned lesson on the IWB while the teacher is working with another small group on a different skill or learning target. When an interactive slate is involved with an additional computer, this now gives the opportunity for 3 separate groups within one class. The initial planning and set up of

three separate groups can be overwhelming, but with collaboration between content teachers within a school and possibly across a district, the demands are lessened and others ideas can fill in where one is stuck. Lessons can also be saved from one year to the next, so the following year the teacher will not be reinventing the wheel, instead just tweaking lessons to meet the needs of the current students. (Knowlton, 2008; SMART Technologies Inc., 2007a SMART Technologies Inc., 2007b)

Though interactive whiteboards are a fairly new technology in the classroom, quite a bit of research has been done on their effectiveness in two primary areas; student motivation and increased student learning. Early on, most of the research was done on how IWBs increase students' motivation to learn and remain engaged in lessons.

“Interactive whiteboards affect learning in several ways, including raising the level of student engagement in a classroom, motivating students, and promoting enthusiasm for learning.” (SMART Technologies Inc., 2006) Researchers have reported that students are more engaged in lessons in classrooms with IWBs and students themselves are reporting that they are more interested in lessons and classes where IWBs are being used. Even student attendance (at higher grade levels and post secondary) has increased in classes where IWBs are in use. (Knowlton, 2008) Throughout the research viewed, it was very commonly noted that students were more engaged in lessons presented with IWBs because they are more enjoyable, faster paced, exciting and interesting. The use of IWBs not only improves learning, but also showed positive impacts on student behavior and student participation. (Smith et al., 2005)

The two possible affects of IWBs, increased student learning and increased student motivation, can go hand in hand. Increased attention and engagement will lead to

increases in learning to a certain point, but there has been more and more research done as of late on the affect of the use of IWBs on student learning specifically. According to an outside report on the affect of IWBs on learning (Smith et al., 2005), when lessons are presented with multimedia resources to supplement traditional information presentation, students can understand more completely due to both the fact that more information was presented in a variety of ways as well as the concepts becoming more realistic and easier to grasp. Teachers have reported that when students are asked what they remember from an IWB lesson, they often responded that they could actually still picture what was taught rather than just remembering the terms and concepts. (Smith et al., 2005)

There have been many studies have been done on the topic of increased student learning by IWB companies themselves as well as outside researchers. A few of these studies are: SMART Technologies Inc. Case Study: Gloucester City, New Jersey (2005), SMART Technologies Inc. Case Study: Bothas Hill, South Africa (2005), The PSWE (Primary Schools Whiteboard Expansion) Project by Manchester Metropolitan University (2004-2006), and most recently the study by the Marzano Research Laboratory (2008-2009).

In Gloucester City, New Jersey, a district considered to be “low performing,” Math Facilitator, Tony Trongone pushed for the integration of SMART Board interactive whiteboards in math classrooms throughout the district. 35 boards were purchased and installed across the district. Trongone then started creating math lessons using the Notebook software. (SMART’s open source software) These lessons were then uploaded on to the district server so that math teachers across the district could use them and curriculum was unified across the district. “The results have been impressive. We were a

district in need of improvement and now we're out of that,' explains Trongone. Math scores in the district's middle school have also improved by 16 percentage points."

(SMART Technologies Inc., 2005b)

At Kearsney College in Bothas Hill, South Africa, they started with just 3 SMART Board IWBs to enhance the teaching and access current technology, but within a year bought 13 more, showing how much they supported the new technology. Teachers at Kearsney College say they have revolutionized their teaching and students report increased enthusiasm and interest in learning. "At the end of last year, our matriculation results in science were the best we have ever had," says (Brendon) Fulton (Kearsney Colleges' IT Specialist). "Fifty percent of the students achieved an A, with a 100 percent pass rate. We believe this is due to good teaching and good use of the SMART Board interactive whiteboard." (SMART Technologies Inc., 2005a)

Researchers at Manchester Metropolitan University conducted an evaluation of the PSWE (Primary Schools Whiteboard Expansion) project from September 2004 to December 2006 to determine the effects interactive whiteboards have on teaching and learning, and whether continued exposure to the technology had an impact on student learning outcomes. (British Educational Communication and Technology Agency (*BECTA*), 2007)

Researchers were interested in how the length of exposure to interactive whiteboards affected students' progress in English, mathematics and science, as well as any additional benefits interactive whiteboards may have had on special needs students, teacher preparation and the overall atmosphere in the classroom. (British Educational Communication and Technology Agency (*BECTA*), 2007)

This report looked at specific groups of students in second grade and sixth grades as well as sub groups of males, females, average achieving and high achieving students, over 2004 and 2005. The PSWE research showed some impressive results. In 6th grade mathematics, both male and female average and above students made about 2 ½ to 5 months extra progress (above average monthly progress) when the IWBs were integrated completely. In 6th grade writing, low achieving males made 2 ½ months of extra progress.

Researchers discovered that interactive whiteboards produced positive effects in the classroom, especially for students of prior average and high attainment. In fact, the results showed that consistent and long-term use of interactive whiteboards had a significant impact on the speed of progress for many students.

(British Educational Communication and Technology Agency (*BECTA*), 2007)

During the 2008-2009 school year, 79 teachers from 50 schools throughout the country participated in independent studies regarding the effect of Promethean (Promethean ActivBoards with ActivStudio Software) technology on student achievement. This research was performed by the Marzano Research Laboratory with Mark W. Haystead and Robert J. Marzano authoring the report. Robert Marzano is a very well known name in the world of educational research and is at the head of his field. This report involved 1,716 students in the group using Promethean ActivBoards and 1,622 students in the control group without these boards.

In this study, one dependent variable was considered: students' knowledge of academic content addressed during a unit of instruction. The primary independent variable of interest was the treatment/control condition—whether students were

exposed to Promethean technology or not. Also of interest were the differences in potential effect of Promethean technology with respect to seven types of moderator variables: school level, grade level, academic content area, length of teaching experience, how long Promethean technology has been used by the teacher, percentage of instructional time Promethean technology is used in the classroom, and teachers' perceived confidence in their use of Promethean technology in the classroom. (Haystead & Marzano, 2009)

The findings of this report suggest that relatively large percentile gains in student achievement were possible when a teacher has 10 years or more of teaching experience, has used the technology for two years or more, uses the technology between 75 and 80 percent of the time in his or her classroom, and the teacher has high confidence in his or her ability to use the technology. (Haystead & Marzano, 2009)

When the results of the Marzano Study were looked at, there were a few points that stood out. When the data was broken down into content area (see Figure 4, below), it was clear that the use of the Promethean ActivClassroom was beneficial in all subjects but saw its greatest impact in the area of science. This may be due to the abstract thinking need to understand science concepts, which the visual aspects of an IWB support (Haystead & Marzano, 2009).

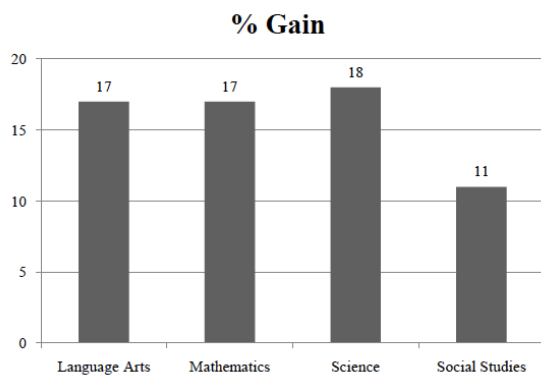


Figure 4. % Gain of students in content areas of Marzano Study.

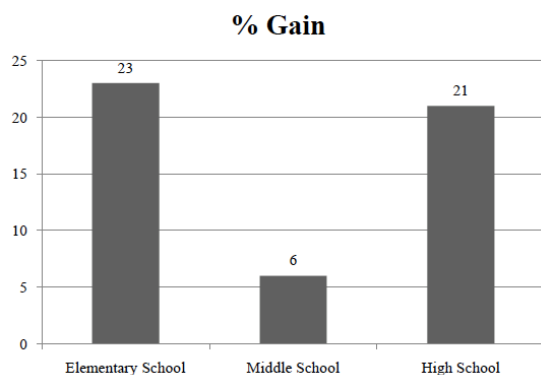


Figure 5. % Gain of students in age groups of Marzano Study.

In Figure 5 (above) the data from the Marzano Study is shown broken down by age group. It is quite clear that the Middle School level did not see the same gains as the other two levels. When the data was broken down further, it showed that 6th grade showed great gains (18 %) while 7th grade showed no gain and 8th grade showed small gains (8%). There were thought to be some problems with the 7th grade data that would require further scrutiny to determine, but 50% of the seventh grade groups showed negative gains. The reasons for this are not clear at this time. (Haystead & Marzano, 2009)

The overall findings of the Marzano Study were that “the percentile gain associated with the use of Promethean ActivClassroom is 17 percent.” “This means that on the average, the use of Promethean technology in the evaluation study represents a gain of 17 percentile points over what would be expected if teachers did not use Promethean technology.” (Haystead & Marzano, 2009) This large of a percentile gain suggests that it is not a result of random factors, but instead, “the 17 percent point increase represents a real change in student learning.” (Haystead & Marzano, 2009)

Overall, the support for the use of IWB in the classroom was overwhelmingly positive whether it addressed increased student motivation or real gains in student learning and achievement. Throughout all of the studies observed, a few keys were needed to increase the positive results, which were; teaching experience, time with the technology by the teachers, and the amount of time the IWBs were used in instruction. All three of these factors point to the fact that the teacher still plays a vital role in using this technology to benefit students. (Haystead & Marzano, 2009; British Educational Communication and Technology Agency (*BECTA*), 2007; SMART Technologies Inc., 2009)

How do handheld student response systems (clickers) affect student learning of science concepts?

Handheld student response systems, also known as audience, personal, and group response systems, are most commonly just called “clickers.” Most clicker systems include a radio frequency receiver (a few are also infrared), software that sits over other programs, and the handheld devices (clickers). The receiver is usually plugged into the USB port on the teacher’s computer and the questions are usually projected on to a

screen. The clickers themselves are usually about the size of a small TV remote.

Students transmit answers by pressing the button that corresponds to their answer choice. (Mula & Kavanagh, 2009; Nelson & Hauck, 2008) “Modern clickers usually have a 10-digit numeric keypad and often some accessory buttons including a power switch, a send button, or function keys that permit text entry.” (Cadwell, 2007)

Clickers allow teachers to ask questions, and the student presses the appropriate button, the computer receives the answers, and then the teacher can choose to show the results on the projection screen. The results can show the correct answer (or not if you choose), the breakdown of students who chose each answer, and the percentage of the class that understands the concept as well as possible misconceptions. Teachers can ask questions to be answered in multiple choice, true/false, numeric, rank order, multiple correct, and some versions even allow short answer formats. (Johnson & McLeod, 2004; Day, 2007) In the K-12 classroom, each student can be assigned a clicker (numerically, based on ID number), or some systems allow students to enter a pin number each time that aligns the random clicker chosen to them in the data system. Different systems have different degrees of data collection, but most systems can “instantly score, grade, tally and report scores for every student, for groups of students, for the entire class, for each lecture, for a semester to date, and so on.” (Nelson & Hauck, 2008)

“The first point about clicker technology that must be emphasized is that clickers in themselves are not a solution to anything.” (CU Science Education Initiative Staff & Wieman, 2009) Clickers are only as good as the teacher that uses them and the manner in which they are used. How one uses clickers depends on the goal of the teacher. Many teachers begin to use clickers to get their students involved and avoid passive, one-way

communication. (Cadwell, 2007) Other goals that a teacher may attempt to accomplish with clickers are to: engage students in active learning; promote student to student discussion based on chosen topics; give feedback to teacher about student understanding; give students feedback about their own learning; as a form of formative assessment to guide teaching and inform learning; give all students a voice, improve attendance and student accountability; model the process of critical thinking to figure out a correct answer; (CU Science Education Initiative Staff & Wieman, 2009; Penuel, Boscardin, Masyn, & Crawford, 2006) reveal student misconceptions (especially important in science); (Cadwell, 2007) prepare for standardized testing; and to reinforce learning, draw connections and build on previous knowledge. (Mula & Kavanagh, 2009; Penuel, et al., 2006)

“Clickers are a powerful, yet simple, way to gauge conceptual understanding and to stimulate discussions,” says Janet de Vry, the University of Delaware’s manager of instructional services in its IT department. (BizEd, 2007) How a teacher chooses to structure a class involving the use of clickers depends on the goal(s) the teacher has in mind. Some common uses of clickers are:

- To quiz on homework/reading
- To recall previously presented information/concepts
- To pull out students misconceptions
- To test/quiz conceptual understanding
- To predict results of a demonstration, experiment, simulation, etc.
- To focus students on key concepts
- To differentiate in the classrooms

- To breakup lectures

(CU Science Education Initiative Staff & Wieman, 2009; Cadwell, 2007).

The *Clicker Resource Guide: An instructors guide to the effective use of personal response systems (clickers) in teaching* (2009), recommends a specific framework for using clickers to meet most student learning focused goals. Step A: Question -Teacher asks (verbally) or projects a specific question (higher level questions are more effective). Step B: Peer Discussion - Students first think individually (maybe answer with clickers individually), then discuss with a partner or small group, focusing on their reasoning and thinking. Step C: Vote - students enter answer on clicker. Step D: Whole-class Discussion - Teacher leads discussion focusing on the “why” and “why not” and student questions. (CU Science Education Initiative Staff & Wieman, 2009) “Structuring opportunities for peer or whole-class discussion appears to be a critical aspect of promoting greater classroom interaction with response systems.” (Penuel et al., 2006)

Eric Ribbens, (2007) an associate professor in the Department of Biological Sciences at Western Illinois University in Macomb, Illinois, started using clickers in the fall of 2006. As he became more familiar with them, the way he used them AND his teaching in general began to change dramatically. From his experience, he shared a few helpful tips and suggestions:

Don't see clickers as simply a new way to give quizzes, and don't be afraid of some chaos. I let my students use their textbook; discuss the questions with each other, etc. In my opinion, if they have to look up the answer, that's learning, and as they argue they are teaching each other! I tell students not to simply share answers, but to work together, and we've developed an effective group dynamic.

Knowing that I trust them empowers them. (Ribbens, 2007)

He also suggests “Be open to change,” using clickers effectively changes how you teach!

Be creative...Combine clicker questions with visuals. Use clickers to collect data or to ask personal questions. Clicker questions are not just conventional multiple-choice questions. Weave graphics into them. Use them to point back at material just covered, and forward towards topics coming up. I use fairly simple clicker questions as reviews and confidence builders, and difficult clicker questions as interest generators and challenges for my good students. Do not see clickers as simply quizzes or tests. (Ribbens, 2007)

Teachers who have used clickers effectively have found many benefits to their regular use. Many teachers of higher education have found that regular use of clickers in class has increased attendance and participation. According to Cadwell, “Physics instructors report that when clickers scores accounted for 15% or more of the course grade, attendance levels rose to 80-90%, preparation for quizzes became more serious, and students were noticeably more alert during class.” (2007) Using clickers in any educational setting allow all students to participate and helps students become active member of the learning experience. (Cadwell, 2007; BizEd, 2007) “Used well, clickers can tell you when students are disengaged and/or confused, why this has happened, and can help you to fix the situation.” (CU Science Education Initiative Staff & Wieman, 2009)

The primary benefit of clickers compared to other, more traditional, audience feedback methods (hand raising, answer cards, individual whiteboards, etc.), is the speed and use of the instant feedback. “The clickers allow teachers to get feedback from all

students, shy and precocious alike...when a student is expected to participate, they all are more likely to be engaged in the lesson,” says Douglas Duncan in *Clickers in the Classroom* (2005). Teachers know immediately if their objectives are being met and can then use their instant feedback to redesign their lesson to meet the needs of the class. Teachers often find themselves giving more quizzes (whether graded or not) so both students and teachers have more data to base grades and learning on. (Ribbens, 2007; Day, 2007; Manzo, 2009) Clickers make constant formative assessment a real possibility. They can provide feedback on student comprehension, allow for timely remediation for individuals or whole class, and reduce clerical work with paper quizzes and tests. (Johnson & McLeod, 2004) “Although teachers cannot always see how students think, the use of ongoing formative assessments facilitated by student response systems, brings them ever closer to that elusive goal.” (Johnson & McLeod, 2004) The effective use of clickers leads learning to be more “constructivist“ or “student-centered” which has been proven to lead to great scientific understanding and real learning of concepts as opposed to memorization of facts. (Penuel et al., 2006)

Students see the advantage of the effective use of clickers in the classroom, also. In classes where clickers are used regularly, students share more “favorable perceptions in terms of active learning, motivation, and providing feedback.” (Nelson & Hauck, 2008) In a comparison of clickers, hand raising, and response cards, students in the clicker group show significantly higher classroom participation as well as higher positive emotion and were more likely to respond honestly. (Stowell & Nelson, 2007) Besides the obvious appeal of the clickers for engagement and motivation, the use of clickers allow students to self identify areas they are struggling with. Students often believe they

understand a concept until they are shown that they do not. This way, students find their problem areas BEFORE a test. Regular use of clickers can also help student to become more invested in the questions. When students know that the clicker questions used in class are the key ideas that will be tested, they try hard and develop ownership for their answers and are more likely to ask key questions when they get answers wrong. (*BizEd*, 2007; Mula & Kavanagh, 2009; Ribbens, 2007)

Many studies have been done about how the effective use of clickers affects student learning, motivation, attendance, participation, and engagement. Johnson and McLeod looked at over 30 studies on clickers and found benefits “including enhanced student engagement, increased subject matter understanding and improved classroom discussion.” (2004) Eric Ribbens found in his own biology class that he had the same number of D’s and F’s, and only a few more A’s after implementing clickers, but that many of his C students bumped their grades up to solid B’s. “Overall, my students averaged about 8% higher, and I believe they learned the material better. Attendance increased about 20% and students seemed to enjoy the course experience more.” (2007) Cadwell (Professor at West Virginia University) learned from a colleague that had begun using clickers regularly that their number of A’s had increased by 4.7% and the number of students that withdrew, or earned D’s or F’s decreased by 3.8% (2007).

Prior research suggests that – when combined with effective questioning, discussion and feedback- classroom network technology constitutes a powerful catalyst for conceptual change, heightened student engagement in class, and, because involvement and feedback for all students is equal, greater equity in science education. (Penuel et al., 2006)

Mula and Kavanagh (2009) found in their action research that when clickers were used regularly, participation levels in class improved, student understanding of course content improved, and students acknowledged class as a positive learning experience. They also found that fewer students failed their course when the clickers were being used. Edens (2006) reported on another study from the Netherlands of more than 5000 students who took either a traditional lecture course or the same course using clickers. Data was collected for 4 years. “The end-of-course exam pass rate was used as an outcome measure. Finding indicated a significantly higher passing rate score mean in classes using the response system as well as a smaller variance in score.” (Edens, 2006)

Nelson and Hauck (2008) from Illinois State University conducted a study on embedding clickers into their Management Information Systems courses. They taught the same course 3 different ways: one with high clicker usage, one with low clicker usage and one with no clicker usage. Over a semester, they found that attendance improved from 68% in the no clicker course to 75% in the low clicker usage course to 86% in the high clicker usage course. Also, course grades improved from an average of 79% and 78% in the no clicker usage and low clicker usage (respectively) to an average of 82% in the high clicker usage course. Nelson and Hauck (2008) also pointed out the correlation between the increase in attendance and the increase in overall grades.

Overall, results of most studies investigated showed that at the very least, the use of clickers improved student’s positive impression of most classes and improved attendance and engagement. Often it was found that with improved attendance and active participation came improved learning. (Nelson & Hauck, 2008; Edens, 2006; Mula & Kavanagh, 2009; Penuel et al., 2006)

Chapter 3: Personal Experience and Conclusion

Interactive technology, in the science classroom, makes learning science more real. Simulations, and the effective use of IWB's allows students to see concepts that were previously invisible and difficult to understand. Add in the use of clickers and students AND teacher begin to see where each individual is in the learning process and helps teachers cater their lessons to the particular students sitting in front of them.

Over the past 4 years I have regularly used, as teaching and student learning tools, PhET interactive simulations, clickers and last year I had the opportunity to use a Promethean ActivBoard. Though each of these newer technologies took time to learn and implement effective use, I believe that all three forms of interactive technology improved student engagement, enjoyment in learning, interest in science concepts, and student understanding of science concepts.

Although the use of interactive simulations in the classroom is just taking off, The PhET Project is leaps and bounds above many other producers of interactive simulations. Due to their research-based design, engaging, interactive features and free to use access, these simulations will be apart of the science classroom for years to come. I have used two simulations (Balloons and Static Electricity & John Travoltage) in a 6th grade static electricity unit that was difficult for students to understand. These simulations have really made the abstract concepts of static electricity, static cling, and static discharge, "real" to students. They can see with the simulations what they cannot see in the real world. These simulations have greatly affected how well student understand these concepts and I have found that students often use drawings now to help explain their ideas which has lead to more complete, higher-level answers on tests.

I have also used, with a lot of success, Electric Field Hockey, Color Vision, Microwaves, Energy Skate Park, Wave on a String, and Wave Interference. Students have loved using these simulations and when the right questions are asked with the simulations, student learning has been improved. I have found that with 6th graders, it usually works best to let the students play around with the simulations for a while first, then stop everyone and direct them to specific directions and questions to answer, then give them some sort of a challenge to accomplish after they have finished. This seems to work the best due to 6th graders tendency to play around whether it is time or not.

I have also used GIZMOS (simulations) from Explore Learning. Some of these simulations are equally as good as some of the PhET simulations except that the GIZMOS are quite expensive and my school district has not purchased the software. Another very good service for simulations (also many video clips including activities and quizzes) is the BrainPOP website (www.brainpop.com). BrainPOP has short video clips with simulations embedded within. They cover the content (some go deeper than others) then have short activities and quizzes to go with the video and reinforce the content. There are thousands of topics (in science and beyond) to choose from.

There are many interactive simulations available to educators, but the benefit of the free service of the PhET simulations as well as their ever improving and research based development, makes them much too valuable to ignore. Interactive simulations are useful as demos (projected on a screen), small group work (for advanced groups OR re-teaching small groups), as well as for whole class trips to the computer lab. Some teachers (depending on students access to the internet) are also able to assign simulations as homework since they are available to all online.

This past school year I had the opportunity to teach with an interactive whiteboard (Promethean ActivBoard). The effective use of an interactive board is a lot of work and a work in progress, but I found many excellent applications for the technology. Though I used the board and projector every single day, the interactivity of the board took some time and planning to implement effectively in class of 30-32 students since only one student can really use the board at a time. I found the board easier to use after I downloaded a few templates for containers (used for matching, venn diagrams, ordered lists, classifying, etc.). Students loved using the board, and I definitely saw improved engagement in lessons where students had continued opportunities to come to the board. I also found the ActivBoard to be very useful and uniquely helpful when I was doing differentiated instruction and/or stations. I would often set up a mini-lesson on the board that students could go through on their own. This freed me up to work with the students who struggle more or to move around the room and work with groups. I have a lot to learn with the ActivBoard, but am enjoying working with it and finding better and better ways to get students actively learning.

The use of interactive whiteboards is on its way to replacing regular whiteboards and chalkboards in most to all classrooms. This is an important step towards having education move in sync with our advancing technological world. With this possibility of universal implementation, training and time to collaborate and develop is crucial. Interactive whiteboards, no matter the brand, are only as good as the teacher who uses them, but at the same time, a teacher is only as good as the training they receive and the time that they are given to develop lessons allows them to be.

Over the past four years I have learned to effectively implement the use of CPS

Clickers (made by E-Instruction) and I have used these clickers in many ways. The most common use of clicker (and the easiest to implement) is the use of clickers to review content. This helps the students review, helps the students identify individual areas they need to focus on, and helps the teacher know areas that students still are struggling with and/or still have misconceptions.

Other ways I have been increasingly using clickers are to introduce concepts and get out misconceptions, during teaching to determine current level of understanding and confusion, and to quiz and test. CPS clickers, when used to quiz or test, are amazing in their data analysis. After entering your classes once at the beginning of the year, students have an assigned clicker that they use for tests. I usually give them a paper test and they enter their answers to the multiple choice, true/false, and matching sections of a test. While students are testing, the teacher can see if a student skipped a problem and have them go back. The teacher can also see right away if many students are struggling with a question, which may hint that there is a problem with that question. Students enter their answers, can go back and change them and review them, and are not officially done until the teacher ends the session. The data is immediately available in 8-12 different formats depending on how the test was entered.

Most recently I have learned to impend the use of the clickers in my pre-teaching and teaching. I have found the clickers to work great when asking the students difficult questions. I have them answer individually, then show the breakdown of answers, but not the correct answer. Then I have groups of 4 discuss the question and come up with the best answer after talking about why they chose the answer they did. I have seen this method really help students develop their higher level thinking skills and deepen their

understanding of the concepts.

There are many different companies that sell different clickers. I have used CPS clickers from E-Instruction as well as ActivExpression clickers from Promethean. From my experience, I have found that each set of clickers has its own benefits and weaknesses. I find the CPS clickers to fit more effectively into my teaching and way of using them mainly due to their Student Monitored Assessment mode and their advanced data analysis. The Promethean clickers have the advantage of multiple ways to answer (likert scale, any type of multiple choice, true false, and short answer with their texting function) therefore are easier to use spontaneously, but their data analysis is no where near the level of CPS's.

The use of interactive technology in the classroom is the way of the future. There are many ways to introduce different types of interactive technology into any classroom. Though it takes a lot of planning and time up front, the more one uses technology in the classroom, the more it will be seen as vital and the easier it becomes to add to one's repertoire.

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