Chapter 1: Introduction

Problem

In the upper elementary grades, several of the science concepts that students are required to learn are fairly abstract (Carolan, Prain, & Waldrip, 2008). For students, the challenge is to understand these confusing abstract concepts well enough to apply their acquired knowledge in practice and during tests, all while retaining their natural passion for the sciences. For teachers, the challenge is to find different ways to make these concepts seem palpable and within the mental grasp of each and every one of their students, irrespective of their students' separately developing cognitive abilities. Making this task still more daunting is the reality that many elementary school teachers struggle to effectively teach the sciences and, many times, the teachers even have an aversion towards or a fear of science (Lazaros & Spotts, 2009; Hackling, Goodrum, & Rennie 2001; Harlen & Holroyd, 1997).

The “solutions” that many teachers often use to make up for their own shortcomings in science many times only harm students (Harlen & Holroyd, 1997). Evidence of Florida’s students’ struggle with science – arguably due, in part, to inadequate teaching methods such as those described above – can be seen just by looking at Florida’s Comprehensive Assessment Test (FCAT) Science scores. The Science FCAT is taken in 5th grade, 8th grade, and 11th grade. When students scores’ are graded, they are given a score of one through five, where L1 is the lowest grade given and L5 is the highest grade given.

Distressingly, at the end of the previous school year (2008-2009), almost one-fourth of fifth-grade students in Florida, 21%, scored the lowest level possible, an L1 (No Child Left Behind [NCLB] School District and State Public Accountability Report, 2009). That same year, 32% of students scored an L2, 34% scored an L3, 10% scored an L4, and only 2% of students
who took the test scored an L5 (NCLB School District and State Public Accountability Report, 2009). If all 5 levels of the Science FCAT were equated to letter grades, 53% of fifth-grade students last year would have scored a D or lower on the Science FCAT. If this same grading scale was applied to both the Reading FCAT – on which 28% of students scored a D or lower – and the Math FCAT – on which 37% of students scored a D or lower – from the same year, it can be seen that the scores from the Science FCAT were significantly lower (NCLB School District and State Public Accountability Report, 2009). Clearly, elementary schools have a need for engaging, stimulating, and effective teaching materials that are not only able to help make intangible science concepts more corporeal for students, but are also able to assist teachers who struggle with teaching science.

**Purpose of the study**

The purpose of this study was to examine how effectively fourth-grade students can acquire knowledge from a text-free, physics-inspired computer game and then subsequently transfer any acquired knowledge to a text-containing, paper-and-pencil assessment, all without the aid of any scaffolding from the teacher. Analysis of this evidence will in turn provide an indication as to whether or not there can be enough transference to justify the use of a wordless, physics-based computer game as an effective educational tool.

**Research questions**

Several previously conducted studies have shown that the use of computer games provides numerous educational and motivational benefits to students. Although the current study
hopes to corroborate the findings of previous research concerning the benefits of computer-game use within the classroom, this study also hopes to answer two specific questions:

- In what ways does the unguided playing of a physics-inspired, wordless computer game enhance fourth-grade students' understandings of certain abstract physics concepts?
- To what extent can fourth-grade students transfer any acquired knowledge from the wordless, physics-inspired computer game to a separate medium – a text-containing paper-and-pencil post-assessment – without any scaffolding from the teacher?

**Hypotheses**

As there are two questions being asked within this study, there are likewise two sets of hypotheses. For the first question – concerning students' ability to learn academic content from the computer game – the hypotheses are:

- A majority of students' scores will be higher on the posttest than they were on the pretest.
- A majority of students' scores will be lower on the posttest than they were on the pretest.
- A majority of students' scores will not vary from the posttest to the pretest.

For the second question – concerning students' ability to transfer knowledge to a new medium – the hypotheses are:

- A majority of students will not be able to correctly answer any questions on the paper-based posttest that they did not already answer correctly on the pretest.
- A majority of students will only be able to answer questions on the paper-based assessment that they originally got correct on the pretest or that require no more than minimal transference.
• A majority of students will only be able to correctly answer questions on the paper-based assessment that they originally got correct on the pretest or that require no more than minimal or moderate transference.

• A majority of students will be able to correctly answer any questions on the paper-based assessment, regardless of the level of transference a question requires.

**Significance of the study**

Numerous studies have shown positive correlations between the use of computer games within the classroom and increased learning gains in science (Dori & Belcher, 2005; Federation of American Scientists, 2006; Henderson, Klemes, & Eshet, 2000; Johnson, 2007; Lazaros & Spotts, 2009). *Crayon Physics Deluxe*, a wordless, puzzle-like computer game engineered based on the laws of physics, could likewise have the potential to be a capable learning aid for elementary school students studying the physical sciences – even though it was not originally meant for use in schools (Purho, 2009). However, in order for this or any other graphics-based computer game to be an effective learning tool, students must not only be capable of acquiring knowledge from the game, but they must also possess the ability to transfer that knowledge to a text-containing paper-and-pencil assessment. Transferring knowledge, or transference, can be defined as the acquisition of knowledge or skills in one context and the subsequent application of that knowledge in a new context (Henderson et al., 2000).

Understanding students’ ability to transfer knowledge between contexts is vital, especially if teachers plan on spending precious class time using a computer game as a teaching tool. This understanding becomes even more imperative if the teacher plans on using the computer game as either a supplemental classroom or home tool that students are expected to learn from without any aid from the teacher. Oddly enough, however, little research has, thus far,
been conducted specifically concerning students’ ability to transfer knowledge from graphics-based computer games to text-based assessments (an exception includes a study conducted by Henderson et al. (2000), who analyzed transference to some extent).

Upon the completion of this study, findings could potentially lead to the prospect that computer games can effectively be used at home or in the classroom during student-led times, such as centers. Conversely, the findings might instead lead to the prospect that a majority of students require some level of scaffolding by the teacher before transference of knowledge from a graphics-based computer game to a text-based context can effectively take place. The results, whatever they may denote, will indubitably add a new dimension to the current body of literature apropos the use of interactive multimedia within the classroom – an area of research that seems to be rapidly growing in popularity (Johnson, 2007; Owston, Wideman, Ronda & Brown, 2009).

**Brief description of the study**

Initially, fourth-grade students will be administered two qualitative interest surveys and a quantitative pre-test, the last of which is based on concepts demonstrated in a physics-based computer game being used in this study. Once the initial testing has been completed, students will have a period of approximately two weeks in which they will play at least thirty minutes at any level of the demo version of the computer game without any scaffolding from the teacher. After this period of game play is over, the fourth-grade students will take a post-test identical to the pre-test taken before the computer game was ever introduced.
Chapter 2: Literature Review

Since the 1980s, technology has been advancing at an exceedingly rapid rate (Rideout, Roberts, and Foehr, 2005). In fact, the newest generation of children has even been dubbed “digital natives” or “generation M,” where “M” stands for media (Rideout et al., 2005, p. 4; Shelly, Cashman, Gunter, & Gunter, 2006, p.8). These nicknames are indeed appropriate, as research by Rideout et al. (2005) has revealed that “83% of young people have a video game console at home” and that even more children, 86%, have at least one computer at home (2005). Along with the increased use of technology in homes, the integration of technology into the classroom has become not only more common, but even highly encouraged by prominent educational organization (Federation of American Scientists [FAS], 2006; International Society for Technology in Education (ISTE), State Educational Technology Directors Association (SETDA) & Partnership for 21st Century Skills, 2007). Research concerning the use of technology in schools is, as such, also becoming more imperative and more widely conducted (Owston et al., 2009). More specific than just the broad category of technology, though, the use of interactive multimedia – such as computer games – within schools is also becoming a fairly popular topic among researchers (Johnson, 2007; Owston, et al., 2009; Wideman et al., 2007).

Computer games in education

There are numerous studies that report a positive correlation between the use of computer games within the classroom and increased learning gains (Henderson et al., 2000; Lazaros & Spotts, 2009; Owston et. al., 2009; Wideman et al., 2007; Subrahmanyam, Greenfield, Kraut, & Gross, 2001); however, the use of computer games in the classroom still has its critics. Many who decry computer games’ educational effectiveness argue that the games may not teach
students problem-solving skills to the extent required to justify the use of computer games within the schools (Henderson et al., 2000). Another concern is the lack of evidence proving that students can “discern between the fun of the game and the skill they are supposed to be learning” (Henderson et al., 2000, p.106).

A significant cause for the skepticism concerning the use of computer games in classrooms is due to the lack of quantitative data and the subsequent reliance upon subjective teacher- and student-completed surveys in the majority of the previous research (Henderson et al., 2000; Owston et al., 2009; Wideman et al., 2007). The student and teacher self-reports that have been so heavily relied upon in many past studies “are known to be subject to the ‘halo effect’ – when participants enjoy an experience, they are more likely to report having learned from it regardless of actual learning” (Wideman et al., 2007, p.17). The “halo effect” is not the only problem that has plagued past research, however. Much of the research concerning computer games’ effectiveness in increasing students’ cognitive skills unfortunately administered the instrument that was to be used for analysis directly after students played the computer game. The consequential close proximity of the game-play to the testing eliminated the opportunity for the research to “address the questions about the cumulative impact of interactive games on cognition” (Subrahmanyam et al., 2001).

Another dilemma concerning past research is that the main focus of these previous studies primarily revolved around only two disciplines – medicine and business (Wideman et al., 2007). This left many disciplines largely under-researched. In addition, the emphasis of past studies has largely been centered on increasing visual intelligence (namely, spatial skills and iconic representation), as opposed to increasing academic achievement in specific content areas (Subrahmanyam et al., 2001). An even more significant hindrance to quality research occurs due
to the rapid evolution of computer games. As a consequence, much of the published research addressing the cognitive and educational benefits of computer games has been conducted with outdated games and software that do not have the same academic capabilities as current games (Subrahmanyam et al., 2001).

Although there is not an overabundance of conclusive research concerning computer games, some high-quality, quantitative studies have been conducted. These studies were found to have utilized quantitative pre-post measurement techniques, control groups, and attitudinal outcome measures to assess the learning impact of games or certain game attributes” (Wideman et al., 2007, p.17). Thus far, most of the previously conducted reliable studies concerning computer games and education have involved the content areas of medicine or business in higher education; however, there have been some reliable studies previously conducted concerning the content area of science at the elementary level (Wideman et al., 2007).

**Teaching science with computer games**

As many researchers have noted, many elementary school teachers either dislike or feel insecure about teaching science (Lazaros & Spotts, 2009; Hackling, Goodrum, & Rennie 2001; Harlen & Holroyd, 1997). Thus, many of these educators tend to teach science in a “decontextualized” or abstract manner, which not only hinders students’ understanding of the content, but also lowers students’ motivation to learn science (Cordova & Lepper, 1996, p.715). As evidenced through several studies, however, science-based computer games have the ability to offer more meaningful and less abstract contexts for teaching science as well as multiple elements for increasing student motivation in the science content areas (Lazaros & Spotts, 2009; Wideman et al., 2007). A select few science-related studies have been conducted using pre- and
post-quantitative measurements – in addition to affective surveys – in an attempt to provide quality results concerning the use of computer games in the classroom. Interestingly, all of these studies showed some level of improvement from pretest to posttest.

One study, by Cordova and Lepper (1996), was based on a math-related computer game; however, the results that this study yielded are certainly relevant to science. Although math and science differ in several ways, both are commonly taught in a decontextualized manner, and both can benefit from a method of teaching that simultaneously lessens the level of abstractness and increases the level of motivation that students feel about learning the subject (Cordova & Lepper, 1996). In the study, elementary school students were given a pretest and a personality survey, and split into groups where each group was given a different version of a math-based computer program (with differing levels of choice and personalization) which they played for three thirty-minute intervals. After they played the game, students were then given a content-related posttest and an attitude survey.

This study provided evidence of improvement in test scores after utilizing the computer game as an educational tool. Students who played the most interactive version of the computer game scored an impressive 20% higher on the posttest that was given to students. Another finding from the study was that the more choice students were given, the more they liked the game. Although the previous finding is one that should be expected, Cordova & Lepper (1996) also found that the students who were given versions of the game that offered the most choice and personalization scored significantly higher on the paper-and-pencil posttest than students who were given a version of the game with less choice and less personalization – even though the content was the same in both versions. These results are evidence that not all computer games are created equally, and that teachers should use digression when selecting a game to be
used in the classroom. For instance, as the study above revealed, linear computer programs that seem to be little more than digital worksheets with animations sprinkled throughout the game – which are the types of computer programs commonly used in schools (Wideman et al., 2007) – are likely to be less effective than computer games that take “into account students’ interests, values, [and] aesthetic preferences” (Carolan et al., 2008, p.21).

Another previously conducted study concerning computer games was Eric Johnson’s study (2007), which sought to find the effectiveness – in relation to both increased content knowledge and motivation – of a self-created computer program to teach electricity to third-grade students. Students in this study took a pretest, played an electricity-themed computer program for forty-five minutes the next day, and then took an identical posttest the following day. The computer program, called Electricity, contains on-screen text that provides students with information about electricity, animations that represent electricity (some of which are interactive), and end-of-section mini-quizzes (Johnson, 2007). Although previous research has shown that computer programs which are comprised of repetitive “drill-like activities” (Wideman et al., 2007, p.14) – such as end-of-section questions – are much less effective than computer programs that are highly interactive, contextualized, and exciting (Cordova and Lepper, 1996), Johnson’s study (2007) still showed a surprising 25% average increase in achievement from pretest to posttest after students played Electricity. The findings concerning students’ motivation to play the game, however, do seem to directly evidence the importance of students’ interest concerning which computer game to utilize. Although students’ evaluation of their own motivation to play the game scored fairly high on the survey, in the comments portion, students had almost as many negative comments as positive comments – seventy-seven negative comments and eighty-seven positive comments – and twenty percent of students said that they
would not play the game again (Johnson, 2007). Although the use of Electricity did increase student achievement, if an even more interactive and contextualized game had been used, perhaps both the percentage increase in achievement as well as the number of students willing to play the game again would have been even higher.

A study conducted by Henderson et al. (2000) sought “to ascertain if students utilized various thinking skills emphasized in [the computer game Message in a Fossil (MIF) and attempted to discover if transference], a higher order problem-solving and life-long learning skill, occurred” from a computer game to a posttest (p. 109). In their study, twenty second-grade students took a content-related pretest, participated in a preliminary interview, played the MIF computer software for at least twenty minutes a day for five weeks (along with participating in other classroom activities concerning related content), and then took a content-related posttest and post-survey. With the MIF software, “the student is a paleontologist who excavates virtual gridded dig-sites by choosing appropriate tools...to discover plant and animal fossils hidden in the ground” (p.107). The study revealed, through anecdotal observations, that by using MIF, students’ vocabulary concerning fossils and biology improved greatly; for instance, classification terms used in student discussions transformed from “slimy animals” to “amphibians” (p.114). After analyzing the posttest scores at the completion of the study, Henderson et al. (2000) also found an average increase in score of 24%. What’s more, the researchers found that students at all ability levels – not just the usual high-achievers or low-achievers – showed improvement from the pretest to the posttest. Concerning motivation, the post-surveys given to students revealed that, along with having a higher increase in achievement from pre- to posttest, girls also had a higher increase in positive attitudes towards science due to the use of MIF. In fact, the girls even “doubled their choice of science-type occupations” after having played MIF (p.123).
Although this study revealed many positive results, students’ ability to transfer knowledge gained from the MIF simulation in order to solve certain problems, “some of which they were not directly exposed to in MIF,” was not found to be significant (p.109).

Although all three of the aforementioned studies had somewhat different goals, content, and methodologies, each study showed mostly positive results concerning both motivation and academic achievement. Specifically, all three of the studies concerning the efficacy of computer games resulted in an average academic improvement (from pretest to posttest) of at least 20%. Although computer games certainly cannot – and should not – replace all other methods of teaching science, the aforementioned research has shown that computer games can be an effective teaching supplement. Furthermore, for those teachers who feel either insecure in their abilities to provide knowledgeable science instruction or who have difficulties with devising engaging, motivation-enhancing science activities, computer games could provide a teaching tool that not only motivates students to learn while helping them to learn, but it could also help a teacher to feel more confident in his or her ability to teach science content effectively.

**Students’ ability to transfer knowledge to a different context**

One reason that teachers and students seem to have difficulty with the content found in science is the level of abstractness that is inherent in many science concepts – especially in the physical sciences. This abstractness makes learning science concepts a monstrous task for many students, especially since truly learning concepts requires students to be able to do more than just memorize and repeat a concept; they must also be able to explain, apply, and even make predictions based on science concepts. However, if even some teachers have difficulty explaining concepts at a level that is cognitively appropriate for children, it can be expected that
many young students will struggle in this area as well.

According to Carolan et al. (2008), “students can accurately visualize and imagine situations and predict outcomes that they cannot verbalize.” Just by playing a computer game, students have the opportunity to identify a problem, use their imagination to construct solutions, predict the outcomes of their solutions, analyze the success or failure of their attempts, revise their solution if needed, and even come to a conclusion about a concept or idea, all without being required to first verbalize their actions. Using computer games as a learning tool, students could scientifically work with concepts in order to help them develop the knowledge required to verbally communicate related information – which would in turn require students to think critically and could stimulate intense scientific discussions (Becta, 2001). The idea that students can learn how to verbally explain a concept through game play, however, is based on the speculation that students will be able to transfer knowledge gained from a computer-generated context to a different context – whether it be oral or written. This aforementioned speculation is not only the focus for the current study being conducted, but has also been somewhat addressed by past research.

Henderson et al. (2000) describes transference as involving the application of “knowledge or skills obtained in one context” to different a context (p.116). For example, learning information from a graphics-based computer game, but then applying that knowledge to correctly answer questions on a text-based assessment, would be an example of transference. Concerning the overall skill of transference, Henderson et al. avow that “achieving new understanding[s] in unfamiliar contexts is crucial to scientific educational situations, and, indeed, for lifelong learning” (p.116). However, the question being posed in the present study, as it has been somewhat addressed in the past, is not whether or not students are able to learn the skill of
transference in general; but instead, how well, if at all, are students capable of transferring knowledge gained from a computer game to another context, such as a written assessment? This question is important to address before giving students a computer game to play in the classroom for educational purposes, as the alternatives to actually being able to acquire transferable knowledge from the game are: merely treating the computer game as a game with no real educational value, or being able to gain knowledge from the game, but then being unable to transfer that knowledge to another context – such as a written assessment. However, if transference of knowledge does take place, a remaining and vital question to ask is this: Is there enough transference to justify the use of this game as an effective educational tool? This is a question that seems to have been somewhat neglected in previous studies.

One study conducted by Greenfield et al. (1996) compared students who played a computer game to those who played an identical board game. In the study, the researchers found that those who played the computer game used more diagrams in their pencil-and-paper written descriptions of what they did than did those who played the game on a board (Greenfield et al., 1996). This study’s results show that the students who played the computer version of the game were successful in transferring some knowledge gained from the game to a paper-and-pencil medium, as they were actually able to give written descriptions of the computer game; however, since this study did not specifically focus on students’ ability to transfer knowledge between electronic and paper-based mediums, the study’s results did not offer a conclusive answer as to how substantial the transference was that occurred. In other words, the use of both verbal descriptions and diagrams could either mean that students had trouble completely transferring the information that they learned to a new context, or merely that the students realized the benefit of iconic representations in what they were trying to describe.
In contrast to the previous two studies, one study conducted by Henderson et al (2000) not only required a much higher level of transference from students – due to the computer program’s main reliance on simulation, as opposed to text – but also specifically analyzed students’ ability to transfer information from a computer simulation to a different context. In fact, one of the study’s main objectives was to analyze students’ ability to transfer knowledge from the simulation-based computer game to related posttests – which involved either hands-on activities or written questions. From the pretest to the posttest given in the study, the students’ overall results increased by 24%; however, the portion of the posttest that this study identified as specifically relating to complete transference of knowledge showed that although transfer did occur, it was not substantial. Overall, the increase in scores from pretest to posttest on the questions that required complete transference was only 13%. Specifically, one question that required complete transference resulted in over a 25% increase in accuracy, one had a 22% increase and another had an increase of 8%; however, one other had a decrease in accuracy of 23%.

One downfall of Henderson’s study was that the specific content in the questions that required transference was not also represented through questions that did not require complete transference. The researchers, then, could not identify if students had missed a question either due to their trouble with the content specifically or due to their inability to transfer their knowledge of the content to a new context.

Summary

With technology advancing at such a rapid rate, the incorporation of technology into the classroom is becoming a more and more appealing idea to many (Johnson, 2007; Owston, et al.,
One specific area of technology that has been increasing in popularity is the use of computer games in classrooms (Becta, 2001; Henderson et al., 2000; Subrahmanyam et al., 2001; Wideman et al., 2007). Although the idea of using computer games as an educational tool does have its critics (Henderson et al., 2007), a significant cause for their skepticism is due to the lack of quantitative data in a majority of previously conducted research (Owston et al., 2009; Wideman et al., 2007). One major concern cited by many of the critics—which is likely spawned by the dearth of adequate research conducted in the past—is the lack of measurable evidence proving that students can “discern between the fun of the game and the skill they are supposed to be learning” (Henderson et al., 2000, p.106).

Along with the numerous studies that have been highly criticized for their lack of measurable data, however, there have also been several studies that have utilized quantitative assessment means—such as pretests and posttests. From these studies, numerous educational and motivational benefits have been discovered. The discovered benefits of computer game use within the classroom range from benefits such as becoming better at multitasking (Becta 2001), enhancing spatial skills (Subrahmanyam et al., 2001), and improving creative thinking, to increasing intrinsic motivation (Cordova & Lepper, 1996), enhancing problem-solving skills (Wideman et al., 2007), and allowing for differentiation of instruction (Johnson, 2007). Although computer games—like all other educational tools—have their downfalls, if specific games are chosen and implemented with care, computer games can provide a gamut of positive effects that, according to most research, will surely outweigh most of the possible downfalls.

Even though computer games have been proven to be beneficial in all main subject areas (Henderson et al., 2000), they have proven to be exceptionally useful in science (Johnson, 2007). This particular finding is significant since many teachers seem to struggle with teaching science
in particular (Lazaros & Spotts, 2009; Hackling, Goodrum, & Rennie 2001; Harlen & Holroyd, 1997). Not only can computer games contextualize science content that is otherwise difficult to grasp (Wideman et al., 2007), but computer games also have been found to increase students’ – especially girls’ – interests in science (Henderson et al., 2000), strengthen students’ hypothesizing skills (Carolan et al., 2008), and more. Additionally, several past studies have even found that the playing of computer games can increase students’ scores on science-based assessments by an average of around 25% (Henderson et al., 2000; Johnson, 2007). These scores can possibly be increased even more if students are given computer games that are based on their interests and enable them to make choices in the game (Cordova & Lepper, 1996).

As can be seen, previous research has provided evidence of several benefits of using computer games as an educational tool in all subject areas – including science; however, at this point in time, little research seems to have been done specifically to determine how well students can learn physics concepts from a contextualized computer game and then apply any acquired knowledge to a different context – such as a written assessment. This matter of transference has seemingly only been addressed in bits and pieces of previously conducted research, and thus, still deserves much more attention.
Chapter 3: Methodology

Introduction

The purpose of this study is to document how fourth-grade students can acquire knowledge through a graphics-based electronic context and then transfer that knowledge to a text-based, non-electronic context without teacher guidance. Specifically, this study will attempt to provide sufficient evidence to be used in answering two distinctive questions.

- In what ways does the unguided playing of a physics-inspired, wordless computer game enhance fourth-grade students’ understandings of certain abstract physics concepts?
- To what extent can fourth-grade students transfer any acquired knowledge from the wordless, physics-inspired computer game to a separate medium – a text-containing paper-and-pencil post-assessment – without any scaffolding from the teacher?

The findings of this study could lead to evidence that computer games can effectively be used at home or in the classroom during student-led times, such as centers. Conversely, this study could instead provide evidence for the level of teacher support necessary before any transference of knowledge from a graphics-based computer game to a text-based context can effectively take place.

Context

The elementary school used in this study is a K-5 school located in Central Florida that has been considered – by the state of Florida – an “A” school for the past eight years (2008-2009 Florida School Accountability Reports, 2009). As far as discipline and truancy problems are concerned, in the 2007-2008 school year, thirteen percent of students at the school had twenty-one or more absences and there were fifteen recorded in-school suspensions and six documented
out-of-school suspensions (Florida School Indicators Report [FSIR], 2008). Of the teachers who work at the chosen school, 59.1% have obtained a bachelor’s degree, 34.8% have master’s degrees, 4.5% hold a specialist degree, and 1.5% have attained a doctorate (No Child Left Behind NCLB School District and State Public Accountability Report [NCLB SDSPAR], 2009).

During the 2008-2009 school year, the total enrollment for the entire elementary school was 908 students, with 149 students in the fourth-grade and 163 students in third-grade (NCLB SDSPAR, 2009). The year that this study took place, in the 2009-2010 school year, both the school enrollment total and the enrollment total for fourth grade were speculated to be similar in number. These approximately 150 fourth-grade students were divided among seven classes. Six of those seven classes were taught by three pairs of teachers who team-taught by splitting up the subjects – one teacher for math and science and one for language arts and writing. Thus, the fourth-grade has three “science and math” teachers and three “language arts and writing” teachers. The seventh teacher’s class, which had 21 students, was self-contained. This teacher taught every subject to her class and was with the same students the entire day.

**Science FCAT**

Last year, during the 2008-2009 school year, according to the No Child Left Behind (NCLB) School District and State Public Accountability Report (2009), a majority of the fifth-grade students at the elementary school used in this study scored a Level 3 (out of 5) on the Science Florida Comprehensive Assessment Test (Science FCAT). This particular FCAT is not administered to any other grade in elementary school besides 5th. The actual breakdown of scores – where Level 1 (L1) is the lowest score given and Level 5 (L5) is the highest score given – was: L1 = 13%; L2 = 27%; L3 = 40%; L4 = 17%; L5 = 3% (NCLB SDSPAR, 2009). Among these scores, the most drastic differences among males and females were that: no females scored a L5,
but over 50% more males were given an L1 than females, (NCLB SDSPAR, 2009). Also according to the NCLB Report, 61% of black students, 50% of Hispanic students, 40% of white students, and 8% of Asian students scored an L2 or below (NCLB SDSPAR, 2009).

Although the scores for the elementary school used in this study were higher than both the district and the state average, they are certainly less than ideal, as more students scored below an L3 than above an L3 (NCLB SDSPAR, 2009). When the scores from the Science FCAT are compared to those of the Reading FCAT, the Writing FCAT, and the Math FCAT that were taken the same school year, it can be seen that the science scores were significantly lower than the scores of the other assessments. For the Science FCAT, 61% of students received a score of 3 or higher; for the Writing FCAT, 95% of students obtained a score of 3 or higher; for the Math FCAT, 82% of students scored a 3 or higher; and for the Reading FCAT, 87% of students obtained a score of 3 or higher (NCLB SDSPAR, 2009).

From these scores, and as evidenced in both chapters one and two of this paper, it is apparent that science is not being adequately taught to students in the elementary school that was used in the study. Likewise, since the state average is even lower than the scores from this school, it can be deduced that the teaching of science in a majority of the other elementary schools in Florida is also sub-par. Learning new and effective ways to teach science to students is evidently a need shared by a majority of elementary school teachers in Florida; thus, conducting more research concerning effective ways to teach science to children is crucial to students’ success in the subject.

**Student population**

Of the 908 students enrolled in 2008-2009, 49% were female and 51% were male. Concerning ethnicity, 56.1% were white, 16.9% were black, 14.2% were Hispanic, 7.8% were
Asian, 0.3% were American Indian, and 4.6% were multiracial. There were no migrant students, but 6.4% of the school population was labeled ELL (English Language Learner). Concerning those at the school with hardships, 28.8% of the students were considered economically disadvantaged and 30.8% of the students were eligible for free and reduced lunch. Out of the school population, 14.9% were considered disabled. Although information on gifted students could not be found for the 2008-2009 school year, during 2007-2008, 3.6% of students were labeled gifted (FSIR, 2008).

As no major rezoning of school districts occurred between the school year that this study took place (2009) and the previous year (2008), for the purposes of this study, the demographics of the previous year's school population was assumed to fairly accurately mirror the student demographics for the entire school population during the 2009-2010 academic year.

**Crayon Physics**

*Crayon Physics Deluxe* is a computer game that was created in Helsinki, Finland in 2007 by Petri Purho and released in June 2007 (*Prototyping of Crayon Physics Deluxe*). In 2008, at the 10th Annual Independent Games Festival held in the United States, *Crayon Physics Deluxe* won the grand prize, known as the Seumas McNally Grand Prize (Think Services Game Group, 2008). In 2009, the game became available to iPhones and to PCs in a downloadable version that can be found at [www.CrayonPhysics.com](http://www.CrayonPhysics.com) (Think Services Game Group, 2008).

**Description**

*Crayon Physics* was installed on several of the computers in the computer lab at the school site, as all of the computers in the lab were able to support the program. Within the fourth-grade classrooms themselves, each classroom had three computers, two of which were
able to support *Crayon Physics Deluxe*. Thus, the game was downloaded on these two computers in each of the three classrooms that represented the experimental group for this study.

The goal of *Crayon Physics Deluxe* is simple: if you move the ball to the star, you win the level. The player has two abilities at his or her control in order to obtain this goal: pushing or pulling the ball, and drawing items that “magically transform into physical objects” which can move the ball – in various ways – to the star (Think Services Game Group, 2008). Both are done with the use of the computer’s mouse – the only control needed in this game. Although the levels become increasingly more complex and the star becomes more difficult to reach as the player passes through levels, the actual complexity of each level is essentially left up to the player. For example, in the first level, the player can easily win by pushing the ball forward into the star; however, the player may instead choose to build a fulcrum and lever system or build a pendulum to reach the star. This feature of the game also allows for players to play the same level multiple times – reaching the star in all different ways that vary in complexity and creativity. Ultimately, in *Crayon Physics Deluxe*, the difficulty and complexity of each level is controlled by the player’s motivation, determination, creativity, knowledge of physics concepts in context, and intrinsic desire to challenge oneself.

**Concepts within the game**

To the best of the researcher’s knowledge, at the time that this research was conducted, the creator of *Crayon Physics Deluxe*, Petri Purho, had not directly mentioned on his website, video blog, or through any other publicly attainable piece of information which particular laws of physics he implemented within the game in. Before this computer game could be used for this study, however, it’s educational potential to teach certain grade-appropriate physics concepts had to be determined. To do so, the researcher closely analyzed the game, and consequently found
eleven physics concepts present within the game. These concepts are: acceleration, mass, force, gravity, levers and fulcrums, inclined planes, inertia (partially), potential and kinetic energy, laws of pendulums, transference of energy, and center of mass (concerning stable and unstable equilibriums).

**Study Design**

In order to answer both of the aforementioned research questions, a teaching style called teacher abdication will be used in this study. The style of teacher abdication requires that students in this study will have contact with *Crayon Physics*, and that the teacher can have contact with *Crayon Physics*, but that the teacher and student don’t have formal contact with each other concerning the game (Carolan et al., 2008). Thus, while this study was in progress, teachers were asked not to include *Crayon Physics* in any of their lessons, not to directly tell students how to solve different levels of the computer game, and not to discuss questions that were on the pretest with students. In addition, teachers were also asked not to schedule any formal discussion time among students concerning *Crayon Physics*. All of the aforementioned requests were made by the researcher in order to ensure that *Crayon Physics* was the only means of scaffolding to participants in this study.

The teaching style used in this study, teacher abdication, was not selected in order to attest that the physical science concepts being assessed will be best learned using this method, or that they should only be taught using this game. In fact, many studies have provided evidence that students should be taught multiple times, in multiple ways, and with various levels of teacher and peer interaction (Becta, 2001; Carolan et al., 2008; Henderson et al., 2000). However, this study is trying to ascertain how well students can learn if a computer program is
considered scaffolding in and of itself and if students are required to transfer any acquired knowledge without the teacher’s assistance. The results provided by this study, therefore, could essentially help teachers determine what level of scaffolding they need to provide when using a computer game as a learning tool in their classrooms.

Duration

As far as the implementation of computer games in the classroom is concerned, many researchers seem to agree that an extended use of the game in the classroom is better than a brief, one-time exposure to the computer game (Becta, 2001; Carolan et al., 2008; Henderson et al., 2000; Subrahmanyam et al., 2001; Wideman et al., 2007). With these findings in mind, this study was constructed so that students could have the opportunity to play the computer game several times over a period of just over two weeks, as opposed to only playing the game once. Specifically, each participating student had a period of more than two weeks in order to play various levels of the game several times for a total of at least thirty minutes.

As fourth-grade is a busy grade in Florida schools due to the standardized FCAT Writing Assessment – the version of the Florida Comprehensive Assessment Tests (FCAT) given to all fourth-grade students, the teachers who participated in the study were adamant about how little class time could be sacrificed for this study. Although a longer time span and more game-play time would have been more ideal, the researcher did not want to make the classroom teacher give up too much of her class time. Consequently, teachers were told that students can play the Crayon Physics for as much time as the teacher can allow the students: the more, the better; however, for this study, the students only had to play the game for a minimum of thirty minutes.

The thirty-minute time frame was chosen after a small, informal pilot study done in 2008 found that a majority of students who were asked to play the computer game could successfully
complete at least the first eleven of the eighteen levels offered in the demo version of *Crayon Physics* – which was the version of the game used for the actual study. Although exposure to all eighteen levels would likely reinforce the concepts found within the game, the researcher has determined that the first eight levels alone potentially expose the students several times to all five of the main concepts, and the additional six secondary concepts, that will comprise the posttest.

**Control Group**

In order to avoid threats to this study’s validity concerning students’ change in scores from pretest to posttest, which could potentially be caused by factors that students are subject to at school other than the use of the game *Crayon Physics*, this study included a control group of two classes in addition to the experimental group of five classes. Although the control group’s results have no relevancy concerning the extent to which students in the experimental group can transfer information from *Crayon Physics Deluxe* to the posttest, the control group is relevant to whether or not student’s in the experimental group score higher on the posttest than on the pretest after having played *Crayon Physics Deluxe*. Specifically, if the average scores of students in the control group change from the pretest to the posttest – whether they increase or decrease, then there is a variable outside of the study that may have caused this change in both groups.

Even though the control group had a teacher separate from the teachers participating in the experimental groups, all fourth-grade teachers at the elementary school used in this study follow the same lesson plans. None of their lesson plans call for the teaching of physical science concepts until several months after the conclusion of this research. Also, even though teaching style can potentially affect students’ acquisition of knowledge just as much as the actual knowledge being taught, since teachers were asked not to discuss *Crayon Physics*, the concepts
found within *Crayon Physics*, or the items found on the pre- and post-assessments used in this study, this factor should not affect this research.

The control group used in this study was asked to take all of the surveys and assessments that the experimental classes took at the same time that the experimental classes took them; however, the control group did not play *Crayon Physics*. In addition, the teacher of the students in the control group was asked not to mention the computer game to students until after the study was over. If the students found out about the computer game from their peers, the teacher was asked to simply mention to students that in a few weeks, they would be allowed the opportunity to play the game; but, until then, they need to wait. After the posttest is administered, the teacher of the control group – as well as the teachers of the experimental group – will be provided with the information needed to inform students how they can download the game at their own house for free if they so wish.

**Procedure**

Prior to the beginning of this study, permission to conduct this research was obtained from the principal of the school, the school district, and the UCF IRB - University of Central Florida Institutional Review Board. Collection of the data took place over six weeks in the fall semester of 2009. Once all teacher consent forms were signed and returned, one of the teachers – and her two classes – was arbitrarily assigned to be the control group. An entire classroom was chosen so that the students would not at all be exposed to the game, which would have happened had they watched a classmate play the game even if they did not themselves. The other teachers – and their total of five classes – were assigned to the experimental group. At this time, all of the teachers were also explained what their role would be in this research under the model of
“teacher abdication.” They were also asked not to use *Crayon Physics Deluxe* in any of their lesson plans until the study was completed. The teachers assured the researcher that they could comply with the above requests since they did not teach physical science until months after the completion of the study.

The next week, parental consent forms were sent out for students to take home to their parents and students were asked to sign a student assent sheet if they wished to participate. Also during this week, the researcher installed *Crayon Physics Deluxe* on the two computers per experimental classroom that were compatible with the game. The game was also downloaded on the computers in the school’s computer lab.

On the last day that parental consent forms could be turned in, the participating teachers were given the general attitude surveys, the multiple intelligence surveys, and the pretest – which they could have participating students (those who assented themselves and have written proof of parental consent) take that day or the next day. Teachers were also told that they could split the administration of the documents up among the two days in any order that is most convenient for them, and that students should have as much time as needed to finish the pretest.

Along with the pretest and the surveys, each student was administered his or her own folder. For confidentiality reasons, the student was required to put his or her name on the folder, but not on the individual papers. When the students completed a paper, he or she placed it in the folder and the teacher collected the folders. When the researcher arrived to collect the surveys and pretest, the individual papers were taken out of the folders one student at a time so that the researcher could write an arbitrary numerical code assigned to that student on all of his or her papers. This same procedure was repeated again with the same folders for the administration and collection of the posttest four weeks later.
Following completion of the pretests, the researcher gave an identical presentation to each of the five experimental classes on how *Crayon Physics Deluxe* works: the goal, the controls, and how to draw “bolts,” pendulums, and a lever and fulcrum system. Students were shown how to draw these items since their test directly relates to pendulums and lever and fulcrum systems, and since the “bolts” are necessary to draw in order to make the abovementioned instruments. Although students were shown how to draw the items, and they were told that “these instruments could help move the ball,” they were not shown how the instruments could move the ball, as that was up to the students to discover for themselves through playing the game. The *Crayon Physics* log sheet was also explained to students on this day and one was placed next to each classroom computer. Extra log sheets were given to each participating teacher in the experimental group so that they could replace a log sheet once it was full. Another of these log sheets was also given to teachers to be used when groups of students play the game in the computer lab.

After every class had observed the demonstration, the game-play phase of the experiment began. This phase lasted approximately two weeks. During this time, all participating students in the experimental groups were allowed time (by their teacher) to play *Crayon Physics Deluxe* in the classroom. Teachers were asked to let that each student complete a minimum of thirty minutes of game-play, and more if at all possible. Teachers were suggested to, if willing, let students play the game before school began, when students finished their work early, as a center during center time, and any other time that the teacher would allow for. Teachers also allowed the researcher to take groups of students to the computer lab in order to play the game. During this game-play phase, whether in the classroom or in the computer lab, students were instructed to fill out the Crayon Physics Log Sheet whenever they played the computer game. All of these
individual sheets were collected by the researcher on the last day of the study.

The day following the last day of game-play, teachers were asked to administer the posttest to students in both the experimental and control groups. The posttest was collected in the same folder and in the same manner that the pretest and surveys were collected four weeks prior. Upon students’ completion of the posttests, the three teachers who were a part of the experimental group were asked to fill out a two-page teacher-questionnaire about their opinions concerning *Crayon Physics Deluxe*. Once this was completed, the researcher collected each questionnaire along with any other research instruments that had not already been collected.

**Testing Transference**

For this study, students were asked to play *Crayon Physics Deluxe* and then attempt to transfer any knowledge acquired from the wordless computer game to a text-containing, paper-and-pencil assessment. In order for the researcher to quantitatively measure the transference that may or may not have occurred for a majority of students, several steps had to first be carried out. Before doing anything else, the researcher analyzed the computer game in order to ascertain what physics concepts are actually demonstrated though the playing of the game. Once concepts were found to be justifiably present throughout the levels of the game, for the purposes of forming the corresponding assessments only, five concepts were labeled as “main concepts” while the other six were categorized as “secondary concepts.” Within the pretest and posttest, each of the five “main concepts” was represented through the formation of three types of differently-formatted, multiple-choice questions each – for a total of fifteen content-based questions.

*Crayon Physics Deluxe* – unlike *Electricity*, and even more so than *Message in a Fossil* – requires a great deal of transference on students’ part due to the game’s textless format and the
corresponding posttest’s text-inclusive format. To avoid the possible dilemma of confusing students’ difficulty with a particular concept with their ability to transfer information – as might have occurred in the study conducted by Henderson et al. (2000), in this study, each of the five main concepts included in the assessments is tested in a format that requires minimal transference, moderate transference, and substantial transference.

One question for each concept (for a total of five questions on the assessment) is structured so that the question is asked in text, but the four answer-choices are all different snapshots from the computer game *Crayon Physics*. Thus, the student taking the assessment is required to read the question and predict which snapshot from the game would be the correct result if he or she was actually playing the game. Out of the three question-types found within the paper-and-pencil assessment, the structure of this question-type requires minimal transference. The transference required is not “none,” however, since there are still some dissimilarities between the structure of these questions and the game – such as an inability to answer a question through trial-and-error in just the assessment and the presence of text in the assessment, but not in the game.

A second question-structure found on the assessments for each concept (for a total of five more questions on the assessment) was structured in such a way that it required a moderate amount of transference compares to the other two question-types. These questions asked a question using text and provided text-based answer-choices; however, a snapshot from the game was included in the question. The inclusion of this snapshot allows a student to see the scenario constructed by the question, but requires the student to predict what would happen next without showing a student what that would look like if they were actually playing *Crayon Physics*. Since this question-type is somewhat more abstract and more text-based than the previous question,
and certainly more abstract than the text-free game, it does require more transference than the question-type described in the previous paragraph.

The third, and last, question-structure was considered one that required substantial transference. The assessments used in this study contained five questions with this structure – one question like this for each of the five concepts. For these questions, both the question itself and the answer-choices were completely text-based – no snapshots from the game were included in either. Since this type of question-structure is more abstract than the previous two question-structures, and since this questions-type contains only text, whereas the other two questions had at least some pictorial reference to the game, this last question-structure requires more transference from the game to a particular question than either of the other two question-types.

In all, both the pretest and posttest (which are identical in their content-based questions) contained fifteen content-based questions. Of these fifteen, five questions required minimal transference, five questions required moderate transference, and five questions required substantial transference. Each of the five main concepts were found in the assessments three times. Additionally, all of the questions on the assessments were formed with fourth-grade students in mind, so no difficult vocabulary or “un-reachable” concepts – concepts that are too conceptually advanced for fourth-grade students’ cognitive development – were used.

Through the three aforementioned question-types found in this study’s assessments, the researcher proposed to quantitatively measure to what extent students can transfer any knowledge acquired from a wordless computer game to a paper-and-pencil, text-based assessment without any teacher assistance during either the game-play of the transference process.
Research instruments and variables

There were several variables taken into account for this study which were obtained through the use of this study’s research instruments. The table below describes the research instruments used in this study, as well as the relevant variables.

<table>
<thead>
<tr>
<th>Research Instruments</th>
<th>Data Type</th>
<th>Administered To</th>
<th>Variables Identified/ Purpose</th>
</tr>
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<tbody>
<tr>
<td>General Attitude Survey</td>
<td>qualitative</td>
<td>student</td>
<td>age, gender, computer access, affinity for computer games, use of computer games, affinity for drawing/coloring, affinity for school, favorite subject, affinity for science,</td>
</tr>
<tr>
<td>Multiple Intelligence Survey</td>
<td>qualitative</td>
<td>student</td>
<td>tendency to lean towards a certain type of intelligence (based on Gardner’s Multiple Intelligences)</td>
</tr>
<tr>
<td>Pretest</td>
<td>quantitative</td>
<td>student</td>
<td>used as a comparison tool for the posttest; used to identify what information students already know</td>
</tr>
<tr>
<td>Crayon Physics log sheet</td>
<td>quantitative</td>
<td>student (experimental group only)</td>
<td>the overall amount of time and the length of the time periods spent playing the game Crayon Physics Deluxe</td>
</tr>
<tr>
<td>Posttest</td>
<td>quantitative</td>
<td>student</td>
<td>used to determine difference in achievement from the pretest to posttest; used to determine which level of transference</td>
</tr>
<tr>
<td>Teacher Questionnaire</td>
<td>qualitative</td>
<td>teacher</td>
<td>used to obtain opinions concerning Crayon Physics Deluxe in reference to both their students and their classrooms</td>
</tr>
</tbody>
</table>

Data Analysis

After all data was collected, the possible fluctuations from the pre-test and post-test were the first to be analyzed for every student. This was done in anticipation of answering the first question of this study: In what ways does the unguided playing of a physics-inspired, wordless
computer game enhance fourth-grade students’ understandings of certain abstract physics concepts? The pre- and posttest scores for the students in each group will be compared to determine if there was a significant change within either group. If there is a significant increase in the control group, this could be an indication that there was a variable outside the experiment which affected student test scores. The control and experimental group will then be compared to see if significant differences exist between the groups.

In order to answer question two – To what extent can fourth-grade students transfer any acquired knowledge from the wordless, physics-inspired computer game to a separate medium – a text-containing paper-and-pencil post-assessment – without any scaffolding from the teacher? – only the experimental group pre- and posttest scores will be examined. Specifically, they will be examined question-by-question to determine the extent of transference which may have occurred.

After these primary analyses, the students will be grouped according to variables (for example, all boys versus all girls) and will be analyzed – for both level of transference and level of achievement difference – as a group according to each of the variables of this study. The variables include: age, gender, race, computer access, affinity for computer games, use of computer games, affinity for drawing/coloring, affinity for school, favorite subject, affinity for science, Gardner’s Multiple Intelligences, and the overall amount of time and the length of the time periods spent playing the game Crayon Physics Deluxe. The purpose of this round of secondary analyses is to find evidence of a possible correlation between the success of a physics-based computer game as a learning tool and any variable determined to be relevant to this study.

Summary

This study took place in a fourth-grade classroom in an elementary school in Central Florida.
Although it was considered an “A” school by Florida, on the Science FCAT, more students still scored below an L3 than above an L3 (NCLB SDSPAR, 2009). From these scores, it can be deduced that even students at this school could potentially benefit a good bit from the use of captivating and effective science learning tools. A tool that possibly meets the aforementioned description is a computer game called *Crayon Physics Deluxe*. This child-friendly, graphics-based, physics-inspired computer game – in which the physics concepts inherently present within the game’s structure include: acceleration, mass, force, gravity, levers and fulcrums, inclined planes, inertia, potential and kinetic energy, laws of pendulums, transference of energy, and center of mass – was used in this study in hopes that it could help provide the researcher with evidence to be used in answering this study’s two questions. As mentioned previously, these two questions were: In what ways does the unguided playing of a physics-inspired, wordless computer game enhance fourth-grade students’ understandings of certain abstract physics concepts? and To what extent can fourth-grade students transfer any acquired knowledge from the wordless, physics-inspired computer game to a separate medium – a text-containing paper-and-pencil post-assessment – without any scaffolding from the teacher?

In order to quantitatively answer these questions, a pre-post assessment technique was utilized – an extra step that, without which, can have led to inconclusive results (Henderson et al., 2000; Wideman et al., 2007). In addition, in order to specifically assess students’ level of transference, the pre- and posttest’s format included questions with three separate levels of text-use – and thus three levels of transference, ranging from answer-choices comprised of snapshots of the computer game (which requires minimal transference) to questions comprised of text only (which requires significant transference).

Once the initial testing was completed, students in the experimental group were given a
period of approximately two weeks in which they played any level of the demo version of the physics-based computer game. During this period, students logged their minutes (which were to total at least thirty minutes in the end) spent playing the computer game on a log sheet. After this two week period of game play was over, the fourth-grade students took a post-test identical to the pre-test taken before the computer game was ever introduced. After all final testing was completed, the possible fluctuations among the pre-test and post-test – and between the three types of questions that involve different levels of transference – were analyzed as a whole group, and then multiple other times according to the different variables taken into account for this study.
REFERENCES


Work Cited


