Reading, Writing and Mathematics: Computer Assisted Instruction as a Learning Intervention (K-9)

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Introduction

As Computer Technology (CT) has permeated everyday life in Canada, so too has the implementation of computers in classrooms. The 1990's saw the widespread of the personal PC and later the mobile phone. The early 2000's marked the advent of e-readers and smart phones followed by the creation of the tablet in 2010. Each form of technology has respectively sparked a boom in academic research (Li & Ma, 2010). For this paper, I will look at all forms of digital screens under the working definition of Computer Technology (CT) to avoid compounding a broad topic.

There is debate about the efficacy of Computer Assisted Instruction (CAI), as research indicates similarities and differences in learning through digital and paper mediums. There are many forms of software and computer technology applied to CAI and reading, writing and mathematics interventions and educational psychologists and educators have been interested in the efficacy of CT in the classroom to help teach students (Woolfolk et al., 2010). The implementation of CT has been tailored to suit the needs of learners in individual subjects with different software designers and different forms of delivery. My purpose was to outline some of the most successful CAI learning intervention methods when compared with paper based learning interventions.

Computer Assisted Instruction (CAI)

Research on CT in the classroom has intensified as the options for implementation have grown. Computer Assisted Instruction is a learning intervention involving CT to teach a specific outcome (Seo & Bryant, 2012). Research shows that the use of CAI in the classroom allows for easy access to information and standardization of materials (Woolfolk et al., 2010). The

networking power of modern computing allows for the possibility for unprecedented, almost instantaneous, sharing of information throughout a classroom, building, or across the world.

There are many forms of popular digital mediums used in CAI such as computers, and more recently, iPads and e-readers (Burns & DeGrande 2012; Ciampa, 2012). Further, each form of CT also presents its unique set of advantages and disadvantages. The most widely used forms of CAI for school aged children throughout the literature include drill and practice, tutorials, simulation programs and games (McClure, 2000; Seo and Bryant, 2009). Implementation of CAI with students with learning disabilities is also a common thread in the literature, it is suggested that this is a population that could benefit greatly from CAI as a supplement to in classroom teaching (Bryant et al., 2009). Research indicates varied success when compared to paper based mediums and traditional teaching methods. Some studies have found better results with digital mediums (Ciampa, 2012) while others have found that paper mediums are more conducive to learning mathematics and how to read and write (Duhon, House and Stinnett, 2012). Further, there are studies that have found no significant difference between the CAI and traditional paper mediums (Wright, Fugett and Caputa, 2011)

There is also the question of the generalizability of the transfer of knowledge from digital mediums to paper and pen based assessments. (Cheung & Slavin, 2013; Duhon, House & Stimmel, 2012). Further compounding the issue, research indicates mixed reviews about the efficacy of CAI over all digital mediums (Burns & DeGrande, 2012; Ciampa, 2012). Students have generally made gains in math (Leh and Jitendra, 2012) and language (McClure, 2000) performance using both computer and paper based mediums. Educators and educational psychologists recognize these gains as paramount to the future social and academic success of

young learners. In other words, it seems that the medium is not as important as is proper implementation of intervention.

CAI: Cognition and Learning:

Learning on screen involves many of the same cognitive processes of learning in a paper medium. There are some unique obstacles that are inherent in learning on screen such as increased cognitive load and multimedia effects (Mayer, 2009). There are several theories of multimedia learning based in cognitive and evolutionary psychology that focus on encoding and memory tasks associated with digital mediums including Information Technology Theory (Miller 1956), Cognitive Load Theory (Sweller, 1988) and the Cognitive Theory of Multimedia Learning (Mayer, 2009)

Cognitive Load Theory contends that there is a relationship between the processing and storing of information based on how it is presented. Digital mediums present the possibility of hypertext and interactive audio and visual components that may increase cognitive load, possibly hindering learning in general or the subsequent transfer of knowledge to other mediums. For this reason CAI designers should be cautious not to increase the cognitive load of the student through an abundance of over stimulating stimuli.

Information Technology Theory of Cognition (IT) contends that short term memory (or attention span) is limited to 7 ± 2 chunks of information (Miller, 1956). Planning, with the use of information chunks, is fundamental to the learning process and learning behaviors. Building on IT (1956), Cognitive Load Theory (Sweller, 1988) is focused on the difficulty people experience when attempting to learn complex information or in multifaceted mediums. This theory has been applied to technical areas but also has implications for CAI as Sweller contends that several general facets of multimedia design can have significant effects on learners. With reference to

aspects of IT (Miller, 1956) such as memory, planning and the organization of information, Cognitive Load Theory offers practical solutions to facilitate the effective design of CAI as to not overload the cognitive capacity of the student. Cognitive Load Theory states that problem solving methods should avoid means-ends approaches which may increase working memory load by implementing goal free problems. Software designers should eliminate tasks that impose a heavy working memory load by physically integrating sources of information. While repetition is essential for learning, software designers should keep information as concise as possible. The goal is to create a learning environment that can increase working memory capacity through the integration of auditory and visual information while avoiding redundancy.

Taking these ideas a step closer to the implementation of CAI, The Cognitive Theory of Multimedia Learning (Mayer, 2009) tackles issues of learning through digital mediums with references to two channel processing - auditory and visual - each with a respective limited channel capacity (dual coding theory). Learning is seen as an active process that requires coherent and efficient filtering, selection, organization and integration of information. As learning is facilitated by the inclusion and integration of both words and pictures (Mayer, 2009), this notion is directly transferrable to CAI when software includes both visual and auditory stimuli. Drawing on facets of sensory, working and long term memory, Cognitive theory of Multimedia Learning states that stimuli should be selected and organized in an attempt to produce schema's that facilitate learning novel material through integration with previous knowledge (Mayer, 2009). Cognitive Theory of Multimedia Learning (Mayer, 2009) posits that software should be designed to provide coherent verbal and pictorial information, guiding learners to relevant information that reduces cognitive load while using a single processing channel.

Students who are of low socioeconomic status may be subject to pressures outside of school that inhibit their class attendance and ability to work at home. As these students are at risk to drop out in later grades and miss class room instruction due to issues at home, Goldin et al., (2014) wanted to know if CAI could help mitigate these obstacles to learning language and math. As Executive Functions (EF) are key to purposeful and goal directed behavior, Goldin et al. (2014) were interested in the transfer of knowledge to paper based testing of language and math of school aged children after a short software-based gaming intervention. They found, consistent with their hypotheses, that the EF gains from the intervention were transferrable to a real world measure – school grades (Goldin et al., 2014). The experimental group played 3 adaptive computer games that focused on working memory, planning and inhibitory skills. The active control group played games that were not effective in eliciting significant gains in EF. When they divided the participants into students who had low attendance and students who had high attendance, Goldin et al., (2014) found students in the experimental group with low attendance scored significantly better on performance scores. Based on this finding, Goldin et al., (2014) contend that CAI may equalize academic outcomes of students with less than average attendance with those who attend school on a regular basis. CAI is beneficial to disadvantaged students because as it mediates low marks and may reduce failing grades, it also improves math and language performance which has broad social and educational factors. (Goldin et al., 2014)

CAI: Reading and Writing

There are many influential factors when it comes to how someone learns language such as phonemic awareness, phonics, comprehension, vocabulary, and fluency (Moats, 2000). It has been suggested that humans are born with a Language Acquisition Device (Chomsky, 1965) however, environmental interactions also play a role in the direction and quality of language

development (Moats, 2000). Early and middle childhood are crucial periods for language development and the early years have major implications for the academic future of students (Goldin et al., 2014). Continuing into adulthood, efficient reading and writing skills are essential in the labor market. For these reasons, it is important to deliver the best educational experience for young learners, especially in the fields of reading and writing.

The contemporary approach to teaching reading and writing in the classroom, the whole language approach, has a broad focus with very specific goals (Woolfolk, 2010). The goal of whole language approach is to teach or improve upon the reading and writing skills and abilities of young learners by emphasizing the use of authentic, real life tasks. whole language approach facilitates the learning and improvement of language skills and abilities by using language to learn and by creating learning opportunities across skills and subjects while respecting the language abilities of teachers and students (Chapman, 1997).

Language comprehension involves a variety of skills such as phonemic and morphological awareness and comprehension. Traditionally, teaching language has been implemented by focusing on areas such as grammar and sentence structure in a teacher centered classroom. Contemporary pedagogy assumes a constructivist, or student centered learning environment with a focus on code based and meaning based approaches. The code based approach focuses on how letters and grammatical structure make the language. A meaning based approach focuses on the interpretation and storage of information or the manner in which students comprehend the material. For this reason contemporary teaching theory for reading and writing emphasizes a balance of code based and meaning based teaching approaches (Woolfolk et al., 2010). A code based approach is a teaching approach that emphasizes that morphological awareness and phonemic awareness are key in learning to read. A meaning based approach is a

teaching approach that employs authentic/practical activities and purposes to emphasize and facilitate reading comprehension.

Wright, Fugett and Caputa (2011) looked at the effects of CAI on vocabulary understanding and reading comprehension in school aged children (i.e., aged 7 and 8). While Wright et al., (2011) found no significant differences in reading comprehension and vocabulary gains between the two mediums, in the digital condition the students were more likely to use assistive materials than the paper based group. In other words both learning interventions were able to elicit gains in vocabulary and reading comprehension, with digital mediums providing the added ease of spelling and grammar tools.

McClure (2000) was interested in the application of CAI to help at risk learners with phonemic awareness. McClure (2000) applied a CAI to 29 Kindergartners in the form of software called Bugs in Space which emphasized bonding single letters to form simple words – or chunks. While some students have no trouble with gaining phonemic awareness through chunking, other students may need to avail of learning interventions to assist them. McClure (2000) contended that CAI based on repetition can facilitate early phonics learning through an active process. The traditional math teaching methods of drill and practice can get tedious for students but it is an effective exercise that can expedite early phonics erudition. McClure (2000) found that student and teacher responses to the program were positive and test results showed gains consistent with student learning. Some students did not like the software as they said that they got bored however, these students were typically high performers. Also many of the students who disliked the program cited the dictionary as their least favorite facet of the software, while typically high performers felt that it was their favorite part of the program. The authors contend that this result implicates the difficulty of using the dictionary and further points

towards the need for interventions that are tailored to the learner's individual needs and skills. This implementation of CAI allowed for students to work at their own pace allowing for the easy tracking of progress and remediation when needed (McClure, 2000). The CAI also proved to be effective in motivating many students. (McClure, 2000)

By mid-elementary school students have reached an extremely important period for struggling learners. There are several key components paramount in learning to read including, phonemic awareness, word study fluency and comprehension (Bryant, Kim, OK, Kang, Bryant, Lang and Son, 2014). Thus, these are areas of interest in research on the impact of CAI on language skills in young learners. Some forms of reading interventions in these situations focus on specific interventions in order to supplement in class learning. Bryant et al., (2014) focused on comparing the use of application instruction (AI) with teacher directed instruction (TDI). The intervention took place during the 30 minute reading period in a special education 4th grade classroom (n = 4). All participants had learning difficulties and scored below average on standardized testing. Both AI and TDI showed positive gains in performance suggesting that both techniques can facilitate learning.

They had four research questions: 1) Is TDI or AI associated with higher levels of student engagement during the reading intervention? 2) Is TDI or AI more effective in teaching word identification to students with reading difficulties? 3) Is TDI or AI more effective than the other in improving reading fluency with students with learning difficulties? 4) What are the perceptions of students towards TDI and AI? The authors found that both forms of instruction reflected a high level of engagement from the students, with slightly levels higher shown by students using Apps. Both forms of instruction ranked high on a social acceptability scale administered to the children after the reading interventions. Students performed better with TDI

but were slightly more engaged with AI. Bryant et al., (2015) believed that with the proper pedagogical research the effectiveness of AI could rival that of TDI if instructions and exercises, based in research, are used. The implementation of iPads to facilitate student engagement in tandem with TDI may present the possibility to achieve both goals. Students may experience increased engagement with teacher guided and well researched AI and improved performance with TDI.

In summary, CAI for reading and writing has been found to be successful in both students with learning difficulties (Bryant et al., 2014), generally in the school aged population (McClure, 2000), and as a motivational tool (Bryant et al., 2014; Aydemir et al., 2012). Language interventions with CAI have shown to improve student test scores in both code based and meaning based tasks (Hall et al., 2000) as well as increase the use of spelling/grammar tools when suited to the learner (McClure, 2000)

CAI: Mathematics

Recent research has instigated a shift to a constructivist teaching approach of mathematics from a traditional teaching approach of mathematics. The traditional teaching approach is based in teacher centered instruction that uses techniques such as drill and practice, and rote memorization (Woolfolk et al., 2010). A constructivist approach allows for **s**tudents to construct knowledge through active involvement in their own learning process (Woolfolk et al., 2010). In addition to different teaching approaches, there are also different focus areas when it comes to teaching mathematics to young students. The most frequent math interventions include those focused on problem solving, math fact fluency and addition, subtraction, and multiplication strategies. CAI is most effective when it is based on contemporary research and implemented by expert teachers (Bryant et al., 2014).

Gross and Duhon (2013) were interested in the use of CAI for Math Accuracy Intervention. With a small sample of three female students, the authors focused on the use of corrective and differential visual and auditory feedback based on accuracy. The students were also given small rewards such as stickers and small trinkets as incentive. The authors used a multiple baseline design, in other words they tested the same student participants across different experimental conditions. The intervention took place 4 days a week, over four two minute sessions. All three students improved their goals from their baseline scores. Each student had different responses to CAI: one student showed a gradual and upward trend while the other two three students showed a more variable response as the intervention continued. The authors attributed this variability to several possibilities to do with individual learner differences and abilities. For the two students who had a varied response to CAI, the complexity of the math was higher and it may be that the intervention did not provide sufficient practice. Gross and Duhon (2013) speculated that these two students may have experienced a growing disinterest in the CAI as they may not have found the task challenging enough. The results of this study suggest that as task complexity increases, CAI may be decreasingly effective. CAI may be less effective for problems that have a larger range of solutions, a larger range of total numbers, and a higher level of math literary skills required to solve the problem. (Gross and Duhon, 2013)

Using immediate corrective feedback, through auditory and visual stimuli, and reward-upon-goal attainment can facilitate CAI (Gross and Duhon, 2013). This process allows students to adjust their response to inhibit wrong answers and increase the possibility of correct solutions. (Gross and Duhon, 2013) The implementation of CAI by the teachers was cited as a possible positive factor in the success of math interventions as it seemed to increase the social validity of CAI and teacher role models. Adding CAI to an existing curriculum, instead of implementing as

an intervention, may more effective in reducing student math difficulties (Gross and Duhon, 2013).

Seo and Bryant (2012) used the Math Explorer program as a CAI for problem solving skills with of students with math difficulties. The intervention took place over 18 weeks and included 4 students in grades 2 and 3. This CAI program used the four step cognitive and three step metacognitive strategies to solve addition and subtraction word problems. All 4 students were successful in meeting and exceeding the criteria for the program and in transferring knowledge to both computer and paper based assessments. However the gains made on computer programs have not consistently transferred over to other mediums. For example, Duhon et al., (2012) evaluated the generalizability of math fact fluency gains across paper and computer assessments. They found that gains made on the computer did not transfer to paper and pencil performance.

Fuchs, Fuchs, Hamlet, Powell et al., (2006) looked at the implementation of CAI to increase number combination skill in children who were at risk for math and reading difficulties. Students were randomly assigned to either math or spelling conditions each including 50 sessions over 18 weeks. Fuchs et al., 2006 were interested specifically in acquisition and transfer effects of the learning medium. Fuchs et al., 2006 found that CAI promoted addition number combinations but not subtraction number combination skills. Transfer from the arithmetic story problems condition did not occur. There were small to medium effects for the acquisition and transfer of spelling measures to reading measures. Typically students gradually gain the ability to count in a procedural manner to get the correct result from single digit addition and subtraction problems – number combination skill. Some students with math difficulties do not develop this skill as quickly as do typically developing children. This is detrimental to academic success as

number combination skill is essential in student progression in the math curriculum. CAI may be a successful learning intervention method for addition combination skills in young children. (Fuchs et al., 2006)

Gunbas (2014) was interested in possible gains in overall mathematics problem solving achievement with the application of a computer based story, a paper based story or through typical isolated word problems. The participants for this study included 128 6th graders from two different public schools in Turkey. To test the efficacy of each condition students were asked to answer math questions presented through each medium. Students in the computer based story showed significantly higher achievement scores than in the paper based story or the traditional method. This could be because the story based learning scenario is more appealing in a computer based setting with visual and auditory cues to facilitate student attention. (Gunbas, 2014). In other words, CAI may offer the opportunity to provide precise and direct feedback to students through audio and visual stimuli in a way that facilitates learning.

Leh and Jitendra (2012) focused on how CAI and teacher mediated instruction (TMI) impacted the problem solving abilities of 25 third grade students with mathematical difficulties in six different classes in Northeast United States. Students received instruction from their classroom teachers during the 50 minute core mathematics program. Students in the student also received additional 50 minutes of intervention with CAI. Students in both conditions achieved similar scores on the word problem-solving measure immediately following the intervention and 4 weeks later. Leh and Jitendra (2012) also found that there was no transfer of knowledge from the CAI to a standardized mathematics achievement test. These results are in line with findings that contend that the quality of instruction may be more influential than the learning environment. (Chang, Sung, & Lin, 2006; Gleason et al., 1990). Based on their findings, Leh and

Jitendra (2012) contend that the success of CAI is contingent on the quality of instruction and software that is based on pedagogical research.

Again, in both students with and without learning difficulties, CAI has been found to be successful as a motivational tool, and as a learning intervention in areas such as problem solving (Gunbas, 2014; Leh and Jitendra, 2012; Seo and Bryant, 2012) and math accuracy (Gross and Duhon, 2013). It should be not understated that it is the quality of the instruction that is key in teaching mathematics not so much as the learning medium. (Leh and Jitendra, 2012)

Summary

While each medium, digital or paper, has its own share of setbacks and advantages, research indicates an overall positive effect of CAI as a learning intervention for reading and math across both. Reading and math skills are essential for the future social and educational success for students. Using CAI as a learning intervention can be a useful supplement for young students who are low SES, have learning difficulties, and as an equalizer for students who may not be able to attend class due to personal issues. CAI allows for the learner to construct their own learning and move at their own pace.

There are several facets that have consistently been cited as key in the implementation of CAI as a learning intervention for reading writing and mathematics. Both traditional teacher centred instruction where the majority of work is completed with paper and pens, and the use of CAI to teach students are effective when certain criteria are met. In other words, the intervention medium, digital or paper based, is not as important as is the proper implementation of intervention. Research consistently indicates that CAI is most effective when it is used to supplement not replace, TDI. The software used in any form of CAI must be based on literature

that focuses on the specific intervention. CAI may be more effective when it is part of a focused organized and consistent intervention led by an expert teacher. When these criteria are met, CAI has consistently shown to improve the grades of school aged children.

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