Learning at Your Fingertips: Reading Comprehension, Mental Workload, and Attitudinal
Differences between Computers and iPads

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ABSTRACT

Learning at Your Fingertips: Reading Comprehension, Mental Workload, and Attitudinal Differences between Computers and iPads

A thesis presented to the Department of Psychology

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Previous research has shown that technology in education has proliferated and become ubiquitous; we see technology in the classroom used for lectures, note taking, and examination. Research has focused on comparisons between computer-based and paper-based platforms, investigating possible differences in testing effects and comprehension. Additionally, attitudes and frequency of technology usage also affect achievement in exams; higher positive attitudes towards technology are indicative of better performance. Relative to computers, iPads boast a more naturalistic interface to allow for more gestural use. With the introduction of gestural technologies like iPads into classrooms, it is important to understand the differences between iPads and computers. The present exploratory study analyzed reading comprehension, mental workload, and attitudes between computers and iPads. Findings revealed a significant effect of mental workload on comprehension, though there was no difference by condition, suggesting that as difficulties of reading on-screen increased, comprehension scores decreased, but that using iPad was not more effective at reducing mental workload when compared to laptops. No other significant results were found. Future studies would benefit by increasing gender

distribution and analyzing longitudinal effects of learning and testing on different platforms but

present findings have implications for future education psychologists, practitioners, and

policymakers.

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Differences between Computers and iPads

As previous research has shown, the proliferation and ubiquity of technology in all facets of people's lives has become evident. Mainly, increasingly we have trends towards technology in the classroom such that individuals are able to take notes, share ideas, to be tested, and even take courses on different technologies. Research has focused on comparisons between computer-based and paper-based platforms, investigating possible differences in testing effects and comprehension. However, the introduction of gestural technologies like iPads has called for a reevaluation to understand the effects of different technologies. The present study aims to fill in that gap by looking at comprehension, mental workload, and attitudes between computers and iPads.

Technology in Everyday and Professional Life

Technological advances have allowed various forms of media platforms to become unquestionably entrenched into the professional (Karr-Wisniewski & Lu, 2010), personal (Karr-Wisniewski & Lu, 2010), and academic lives of people of all ages (Bowman, Levine, Waite, & Gendron, 2010; Carrier, Rosen, Cheever, & Lim, 2015). Devices such as laptops and smartphones have become integrated into the daily life of people all around the world, so that it is not an uncommon sight to see a child or a teenager on an iPad or smartphone. In fact, a study done in 2013 exemplified this access in a national survey of 802 teens, with 78% reporting having a cellphone and 23% reporting having access to a tablet computer (Madden, 2013).

Technological advances have allowed for workplaces to run more efficiently, with various tools, systems, and applications becoming more available to employees, allowing for increased productivity (Karr-Wisniewski & Lu, 2010). However, arguably a point exists at which technology falls down the curve of productivity into overload (Karr-Wisniewski & Lu, 2010). While no framework model exists to explain possible overload at work (Karr-Wisniewski & Lu, 2010), similar effects have been noted in the academic world and studied more thoroughly.

Technology in Academia: A Closer Look

Technological advances have changed the way teaching and learning have been approached (Calisir & Gurel, 2003), with technology-enhanced classes making student learning more interactive, and thusly more fun and attractive for students (Eyyam & Yaratan, 2014). As education continues to trend towards this use of technology, an increase in reading materials on screen rather than on print has been seen, as in eBooks (Rockinson- Szapkiw, Courduff, Carter, & Bennett, 2013). Students have also increased their use in taking notes on screen than on print (Bui, Myerson, & Hale, 2013; Chiu, Wu, & Cheng, 2013; Kauffman, Zhao, & Yang, 2011), and assessments are increasingly on screen rather than on print. Various studies as reviewed below have looked into how these transitions may help or hinder student achievement and comprehension.

Testing Effects on Technological Platforms

With the proliferation of technology into the educational setting, an accelerated transition to computer-based testing has occurred, reflecting changes in pedagogical methods (Piaw, 2012). Much research has examined these differential effects, especially within the paper-based testing (PBT) and computer-based testing (CBT) paradigm (Ackerman & Lauterman, 2012; Chua & Don, 2013; Ie, Haller, Langer, & Courvoisier, 2012; Kim & Huynh, 2008; Piaw, 2012). These

CBTs have ranged from high-stake assessments like state exams to low-stake assessments like class tests (Swanson, 2006).

The standards for developing CBT require that equivalent test scores be established for the new CBT and PBT (Commission, 2004). Experiments using the Solomon four-group design have suggested that there are no significant testing or treatment effects for test performance and that individuals who use either CBT or PBT tend to receive comparable scores (Chua & Don, 2013; Kim & Huynh, 2008; Piaw, 2012). In fact, CBT has been found to reduce testing time and increase participant motivation (Chua & Don, 2013). Overall, research has suggested that PBT and CBT are similar in format and results.

Comprehension in On-Screen Reading

Comprehension in exams goes beyond simply reading a passage; it requires that readers connect and synthesize information from different parts of the text, formulating key themes and ideas (Coiro, 2011; Coiro & Dobler, 2007; Foroughi, Werner, Barragán, & Boehm-Davis, 2015; Margolin, Driscoll, Toland, & Kegler, 2013). As the amount of reading on screen increases, research has focused on determining whether comprehension using technological interfaces is comparable with comprehension using paper formats. These studies often report that mental workload, or how mentally and physically demanding a task is, goes hand-in-hand with comprehension and that mode of test administration does have a negative effect on comprehension scores. Research has suggested that it is more difficult to read long passages from a computer screen, and that longer passages require more mental effort to fully comprehend and synthesize texts (Mead & Drasgow, 1993).

Difficulties, Discomfort, and Cognitive Load, Oh My

Difficulty has often been examined under the lens of cognitive load or mental workload within technological based contexts (Ackerman & Lauterman, 2012; Kim & Huynh, 2008). Cognitive load theory (CLT) is a memory and instructional theory that states that during the learning process, cognitive processes interact between working memory and long-term memory to ensure deeper encoding (Agostinho et al., 2015; Ayres & Paas, 2012; Sawicka, 2008). However, working memory has a limited capacity that is sensitive to complexity of materials (Ayres & Paas, 2012), integration of materials, (Schwamborn, Thillmann, Opfermann, & Leutner, 2011) or poor instructional design (Ayres & Paas, 2012; Schwamborn et al., 2011), regardless of the platform through which material is being learned. Research on CLT has found varying results as it pertains to technology, some of which being positive and in favor of technological use for learning (Agostinho et al., 2015; Schwamborn et al., 2011), and others negative (Carrier et al., 2015; Karr-Wisniewski & Lu, 2010).

When reading text passages on screen, individuals often report eyestrain and mental fatigue because of increased mental workload (Ackerman & Lauterman, 2012; Kim & Huynh, 2008). Other difficulties have been related to display orientation, screen brightness, font type and size, difficulties in orientation amongst pages and inconvenience in navigation (Ackerman & Lauterman, 2012). These difficulties attenuate the inclination towards using technology and tend to lead to poorer comprehension during learning. However, many of these difficulties may be because of issues in early technology that have since then been remedied. Devices such as iPads and Kindles use reflective light, mitigating screen effects, and Amazon states that Kindle is outselling books (Kolakowski, 2011). Still, research investigating differences between CBT and

PBT suggest that participants find CBT as more difficult than PBT, though the magnitude of those differences were small (Kim & Huynh, 2008).

Furthermore, a study done by Mayes, Sims, and Koonce (2001) found that while there were no differences in performance, mental workload was negatively related to reading comprehension scores (Kim & Huynh, 2008; Mayes, Sims, & Koonce, 2001). This suggests that while participants read at the same rate on both platforms, when specifically analyzing comprehension, screen-based tests tend to increase cognitive load, leading to a negative impact on subsequent learning and remembering of information. That may be because when reading online, people tend to read selectively, engaging in more scanning and keyword spotting which does not lead to better reading comprehension. However, engaging in these methods requires less cognitive effort.

Other complaints are due to the scrolling effect. When reading on-screen, instead of flipping pages students have to scroll down to access the next page. Many students have reported that scrolling interferes with test-taking abilities (Kim & Huynh, 2008). In fact, studies comparing reading tests on paper and on screen have found that individuals perform significantly better reading on paper. This was hypothesized to be due to increased spatial mental representation of the physical layout of the text, such that individuals in paper conditions were able to relocate information based on that mental representation which led to higher reading comprehension scores (Mangel, DeStefano & LeFevre, 2007). This spatial mental reconstruction is less accessible on screen due to the scrolling effect, and thusly leads to lower comprehension scores.

Additionally, with the ubiquity of technology in education, a theory of cognitive flexibility in the realm of online reading has been put forward (Coiro, 2011; Coiro & Dobler,

2007). This theory states that online reading demands a larger scope of knowledge of flexible comprehension procedures such that if reading begins on technology, those individuals are better able to move past any difficulties and effectively comprehend material. Previous studies have found that fifth and sixth grades are able to strategically skim, scan, search, and navigate on-screen texts, and with the use of prior knowledge, have successful reading experiences. Conclusively, it is determined that skilled readers implement use comprehension techniques that are similar to and more complex than techniques used by paper-based readers (Coiro, 2011).

Attitude Adjustment: How Tech Leads to Success

Attitudes and frequency of technology usage are two factors that influence comprehension, affecting motivation and achievement towards student success. Particularly, one study tested achievement and attitudes within two groups: one that was taught lessons in mathematics on technology and was that was not. Researchers found that educational technology not only affected the success of students, but also was indicative of higher positive attitudes towards technology (Eyyam & Yaratan, 2014). The more time students spend on technology and the Internet, the better they get at navigating those environments fluidly which enhances positive attitudes towards technology and reflects in their performance throughout learning on those interfaces (Eyyam & Yaratan, 2014; Wu & Tsai, 2006).

Despite this general understanding, the concepts of attitude and frequency of technology usage are understudied. This is because of the lack of consensus on how to operationalize and measure attitudes towards computers. Some research has tried to analyze affect towards computers, perceived usefulness, perceived control and expertise, and behavioral components towards computers (Selwyn, 1997), while others have also included frustration with computers, enjoyment of use, and education of computers (Smith, Caputi, & Rawstorne, 2000), focusing

more on the experience of using computers. Even less research has included newer technologies into their measures like smartphones or iPads. One particular survey developed by Rosen, Whaling, Carrier, Cheever, and Rokkum (2015) assesses multiple components of media and technology usage and attitudes such as smartphone usage, social media usage and frequency, emailing, video gaming, and watching television. This survey covers technology usage beyond computers, measuring affect and experience towards technology (Rosen, Whaling, Carrier, Cheever, & Rokkum, 2013).

Inclusion of iPads: A New Domain

iPads boast a more naturalistic interface, allowing for more gestural use as individuals use their fingers to switch between applications and read. The importance of touch to the perceptual system is best reflected in our ability to experience the environment through active exploration, and thus similarly, this same feeling can apply to the virtual reality by navigating spaces on the Internet which further develop learning (Flewitt, Kucirkova, & Messer, 2014) . This gestural interface speaks towards the dichotomous nature of sensory experiences: the ability to touch and also being touched (Flewitt et al., 2014). Mirror neurons further exemplify this point in that when we observe another individual perform an action, our neurons for that action are also activated. This suggests that touch and gesture play an important role in learning and development. Gesture specifically plays an integral role in the development of communication; infants use point gestures to indicate what they want, and a toddler's playing and drawing in sand leads to written language capabilities. Thus, gesture-integrated devices like the iPad have an immediate hand-surface connection that assists direct learning as opposed to computers, in which a mouse mediates touch (Flewitt et al., 2014).

Readers claim that iPads are useful by providing the portability of books while also having the search and storage capabilities of computers (Larson, 2010), giving the ability to share books between home and school. Furthermore, when iPads are compared to computers, readers often express feelings of physical discomfort when reading on computers that they do not feel on iPads (Larson, 2010). Knowledge is legitimately right at students' fingertips (Jodie & Dennie, 2012), such that students can use this gestural and portable interface to promote learning in any situation (Ackerman & Lauterman, 2012; Hutchison, Beschorner, & Schmidt-Crawford, 2012; Wu & Tsai, 2006). Learning can occur at home, at school, in transitions, in groups, in pairs, or individually, thus making learners active rather than passive recipients of information (Flewitt et al., 2014; Mavri, 2014). The naturalistic nature of iPads means that they can be implemented into classrooms with younger children (Flewitt, Messer, & Kucirkova, 2015), building on those gross and fine motor skills and being personalized for smaller individuals as well, instead of having to teach students how to operate a device such as a computer over a long period of time.

Increasingly, K-12 institutions are transitioning to iPad inclusive classrooms; thus, it is important to understand the effects and differences between iPads and computers (Waters, 2010). Unfortunately, relatively few studies have looked at the impact of iPads on typically developing student populations (Ackerman & Lauterman, 2012; Hutchison et al., 2012; Jodie & Dennie, 2012).

Previous studies have found that students using iPads to annotate reading passages score 25% higher on questions, and that iPads increase engagement in learning, despite being somewhat distracting in classrooms (Hutchison et al., 2012). Several applications are available on iPads that allow for interactive learning supporting better understanding of critical materials

in class (Hutchison et al., 2012; Jodie & Dennie, 2012). Additionally, some researchers believe that iPads are gesture-based and thus, mimic naturalistic communication which further supports learning (Agostinho et al., 2015). One particular observational study was conducted over a semester, in which the professor and students alike used iPads in and outside the classroom to complete assignments (Jodie & Dennie, 2012). Students performed well in class, engaging in collaborative works that were simplified by the iPad, which allowed for deeper understanding (Jodie & Dennie, 2012). However, again students reported tensions in the iPad being a distraction during classroom time (Jodie & Dennie, 2012) .

Current Study

Narrowing in on the technology-driven trends, the current study was an exploratory study, looking at differences between iPads and computers in comprehension and mental workload. In this study, iPads and computers were used for learning and testing, resulting in two conditions: computer-based learning to computer-based testing and iPad-based learning to iPad-based testing. It was hypothesized that participants in the iPad condition would perform better than those in the computer condition, scoring higher in comprehension and lower in mental workload due to iPads being more intuitive and gestural, and thusly a more interactive and motivating technology.

Additionally, the present study assessed mental workload, frequency of technology use, and attitudes towards technology usage between computers and iPads. Because of the touch screen capability and efficiency of iPads, it was predicted that students who read on iPads would report less mental workload. Subsequently, reported lower mental workload will predict an increase in comprehension scores, as these individuals will be able to use their working memory to focus on the task rather than be distracted by difficulties from the technological platform.

Furthermore, individuals with attitudes that are more positive and who report higher frequency of technology usage will perform better than those with negative attitudes or those who report lower frequency of usage due to cognitive flexibility.

Methods

Participants

The sample in this study was composed of 55 participants, 18 Males and 37 Females. Participants' age ranged from 18-23 and largely identified as first-year students from a small liberal arts university ($N = 35$) who were either Asian/Pacific Islander ($N = 25$) or White/Caucasian ($N = 24$). In total, the sample consisted of three different types of students: those who were recruited through the introductory psychology course pool, those who could receive extra-credit for participating, and those who were not enrolled in psychology courses and were recruited by posting flyers around campus. The latter were compensated with five dollars. Participants were randomly assigned into conditions, with 26 participants in the laptop condition and 29 participants in the iPad condition.

Measures

Reading Comprehension. All passages and reading comprehension questions were derived from previous Scholastic Aptitude Tests (SATs), a test administered to millions of students. These measures were used as they were similar to those used in a previous experiment (Foroughi et al., 2015). The SAT exam tests reading, writing, and mathematic skills learned in school that are critical for success in higher education. Furthermore, SAT reading comprehension skills were tested because of the transition towards high-stakes exams being given on technological interfaces rather than on paper (*Cronbach's $\alpha = 0.93$*). The SAT has already made this transition.

Mental Workload. The NASA-Task Load Index (NASA-TLX) is a subjective workload assessment that derives overall workload based on a weighted average of six subscales: mental demands, physical demands, temporal demands, own performance, effort, and frustration. It is typically used to assess workload in multifarious human-technology environments and has often been used in the context of learning on different technologies (*Cronbach's α*s > 0.80; see Appendix C).

Media Usage and Attitudes. A subset of questions from the Media and Technology Usage and Attitudes Scale was used to assess everyday usage of technology-based media and other activities (Rosen, Whaling, Carrier, Cheever & Rokkum, 2013). Our subset included 25 questions that assessed specifically frequency of usage and attitudes towards technology (*Cronbach's α*s = 0.80 – 0.91; see Appendix D).

Procedure

Participants came to an office to complete the consent process. This included giving participants a small story describing the study, possible risks and benefits, and what they would be doing, having them read the form, ask any questions, and finally sign the consent form. After informed consent was provided, participants completed a pretest, given on paper. Then, participants read two passages and completed 20 reading comprehension questions on the technological condition they were assigned. These reading passages and comprehension questions were similar to a design by previous researchers who adapted portions of the SAT exam and examined comprehension on undergraduate students (Foroughi et al., 2015). Participants then filled out the NASA-TLX survey and the subset of the Media and Technology Usage and Attitudes Scale, After finishing, participants completed a demographics questionnaire, and then were debriefed, and were awarded credit or extra credit in their course. Participants not

from the Psychology subject pool were compensated with $5. Overall, the task took 30 to 45 minutes to complete.

Results

Principal Axis Factor (PAF) with oblimin rotation was conducted on the entire sample (n = 55) on the items from the NASA-TLX. The item 'performance' was removed, as it did not hang well with the other items (Cronbach's α if Deleted = 0.76). The analysis with the rest of the five items yielded one factor, which is referenced as mental workload, explaining a total of 42.80% of the variance. PAF was also conducted with questions regarding attitudes towards technology as well as with questions regarding frequency of technology usage using a varimax (orthogonal) rotation, respectively. The results of factor analysis revealed two factors: attitudes (toward technology use) with nine items and usage with five items, with corresponding Cronbach's alpha at 0.81 and 0.73.

Initial univariate analyses were conducted to look at the distribution of comprehension test scores by technological platform condition. Descriptive statistics of the key variables are presented in Table 1. A visual inspection of the histogram of comprehension scores by the computer condition showed a symmetrical distribution that was unimodal and mesokurtic. Additionally, side-by-side boxplots of reading comprehension scores by technological platform condition revealed similar distributions of central tendencies and variance (See Figure 1). The histogram of comprehension scores by the iPad condition was negatively skewed, unimodal, and leptokurtic. Additionally, Q-Q plots established normality for both the iPad and Laptop conditions, so no data transformations seem to be necessary.

Furthermore, bivariate analyses of comprehension score by mental workload, attitudes towards technology, and frequency of usage, respectively, were analyzed. A visual inspection of

the scatterplot between comprehension scores and mental workload revealed a strong, steep negative linear association ($r = -0.51$, $p < 0.001$; see Figure 2). The scatterplot of comprehension scores and attitudes towards technology showed a moderately positive trend ($r = 0.04$, $p = 0.75$; see Figure 3), and the scatterplot of comprehension scores technology usage showed no association ($r = -0.23$, $p = 0.09$; see Figure 4), with one potential outlier (*Mean* $_{Comprehension}$~ 3.40, *Mean* $_{Usage}$ ~ 0.83). Additional simple correlations were produced and there a strong correlation was found between comprehension scores and mental workload ($r = -0.51$, $p < 0.001$) (See Table 2). No other significant correlations were found.

Three ANCOVAs were conducted in order to analyze the effects of mental workload, attitudes towards technology, and usage of technology, respectively, on comprehension test scores between computers and iPads, The ANCOVA run to test the effects of mental workload on comprehension scores found a significant main effect of comprehension scores, $F(1, 52) = 17.37$, $p < 0.001$, $p\,\eta^2 = 0.26$. This suggests that controlling for the technological condition participants were in, comprehension scores were significantly related to mental workload, $\beta = -5.15$, $t(52) = -4.29$, $p < 0.001$. No differences were found due to technological condition participants were placed in, controlling for mental workload $(F(1, 52) = 0.05$, $p = 0.83)$, attitudes towards technology $(F(1, 52) = 2.02$, $p = 0.16)$, or technology usage $(F(1, 52) = 0.46$, $p = 0.50)$. There was no significant relationship found in attitudes towards technology and comprehension scores, $F(1, 52) = 0.04$, $p = 0.84$, or the frequency of technology usage and comprehension scores $F(1, 52) = 3.06$, $p = 0.09$, controlling for platform conditions. Relevant interactions were tested and no significant interactions were found (*Cohen's d* $_{Mental\ Workload*Attitudes}$ = 0.05, *Cohen's d* $_{Mental\ Workload*Usage}$ = 0.08).

Discussion

The present study evaluated comprehension, mental workload, attitudes towards technology, and frequency of technology usage between computers and iPads. Specifically, findings of this study suggest that iPads are not more effective at reducing mental workload when compared to computers; for both conditions, comprehension scores decreased significantly as reported mental workload increased. These results have the potential to influence changing academic pedagogy, specifically for education researchers, programmers, and policymakers.

Mental workload did not differ between the two technological conditions that participants were placed in. It is possible that participants experienced and reported mental workload due to the reading comprehension task. Many participants commented negatively on how similar the task was to the SATs. As current technological trends increase, there is a gradual increased transition from assessments that were once given on computers to now being given on iPads (Schaffhauser, 2012). Specifically, the Smarter Balanced Assessment Consortium (SBAC) and the Partnership for Assessment of Readiness for College Careers (PARCC) who both develop assessments to measure progress in math and English and language arts, are currently considering using platforms like the iPad to perform testing (Schaffhauser, 2012). While the iPad provided a more gestural and intuitive platform for reading engagement, reading particularly for high-stake exams sustained high levels of mental workload and stress related to those exams. Additionally, Pearson, a company that frequently administers intelligence testing, has developed a tablet-based digital platform called Q-interactive that is only supported by the iPad (Dumont, Viezel, Kohlhagen, & Tabib, 2014). Similar to the Solomon four-group design, Pearson has

established equivalency using one test across paper- and iPad-based administration (Dumont et al., 2014). However, no further studies have been conducted to evaluate possible behavioral or experiential differences, as intelligence testing on an iPad is novel.

Furthermore, classrooms that have iPad intensive exposure have reported many advantages and disadvantages. While students are enthusiastic about the size, portability, and extended battery life, concerns arose in difficulties pertaining to reading. As much of the text was small, students would have to increase the size to make the make the text more readable (Marmarelli & Ringle, 2011). Additionally, many students complained that reading and annotating text was difficult due to the scrolling effect, particularly scrolling horizontally to read sentences to completion (Marmarelli & Ringle, 2011). Similarly, the scrolling effect potentially could have increased reported mental workload and produced lower scores, as participants were free to zoom in and zoom out of the text as they pleased on either the computer or iPad.

Although differences in mental workload were expected between iPads and computers, previous research on ocular movement has found that mental workload is not different between these two platforms. Specifically, while there are no differences between computers and iPads, one study found a significant difference between those two platforms and the Kindle tablet, suggesting that people strain their eyes more when reading from a Kindle than from an iPad, computer, or printed book (Rosenfield, Jahan, Nunez, & Chan, 2015; Zambarbieri & Carniglia, 2012). Furthermore, this study found that reading from an iPad or computer is no more difficult or uncomfortable than reading from a printed book, which is consistent with our finding of significance in mental workload that does not differentiate by platform (Zambarbieri & Carniglia, 2012).

Although the current study provides further insight into the usage of iPads, this information is limited in several ways. Gender was evaluated as samples within the study were relatively small which led to a disparity in gender distribution. The present study would have benefitted by a comparison between males and females, as prior research has shown that gender differences typically exist for technology (McKenney & Voogt, 2010; Shashaani & Khalili, 2001; Tsai, Lin, & Tsai, 2001; Wu & Tsai, 2006).

Additionally, methodological concerns were raised, as the iPad should have had a flip-page mechanism for reading passages rather than a scrolling downward to read passages. While the scrolling maintained similar experiences for participants, eBooks on iPads and Tablets typically have pages that are flipped through. However, as aforementioned, participants were free to zoom in and out of passages so the scrolling effect could possibly have maintained regardless of the flip mechanism.

Given this prior work, future research would benefit by also including the flip-page mechanism as well as mixed conditions of iPad-based learning to Computer-based testing and vice versa as it is not uncommon for students to write notes on one and to be tested on the other. Additionally, most participants had prior exposure to iPads and so, repeating this study in a school that has not implemented iPads into their curriculum potentially could show mixed results as well. Furthermore, as the reading passages were relatively short in length, increasing the amount of reading completed may also lead to potential increases in mental workload.

Moreover, the present study assessed testing on technological platforms and not necessarily learning. As learning is more temporal, the present findings do not necessarily suggest that there is no difference in learning by using different platforms. Future studies would benefit by exploring a longitudinal experimental design of learning within a classroom with tests

integrated on different technological platforms to fully grasp the impact of technology on learning and testing.

Despite these limitations, the current study provides further insight to the inclusion of iPad into comprehension and testing. Given previous research and the findings of the current study, with the iPad being no better or worse in reducing mental workload than computers, there is a valuable impact of introducing iPads to school districts. As iPads are cheaper to purchase and less difficult to maintain and handle, researchers and policymakers have the ability to effectively decide on the implantation of iPads into curriculum across all schools. Currently, iPads are only in selected schools and districts, but nationwide pedagogical change would decrease current disparities that lead to aggrandize class differences for students within states and county education systems. That is, introducing iPads to all students would lend them to have similar experiences and exposure to newer technologies. As iPads are a novel, gestural, and interactive interface, further research into their implications in learning will continue to expand the gap in literature and impact educational change.

Appendix A

Table 1.

Descriptive statistics of key variables by platform conditions.

	Computer *M (SD)*	iPad *M (SD)*
Comprehension	0.60 (0.16)	0.62 (0.15)
Mental Workload	5.23 (1.51)	5.02 (1.62)
Attitudes	4.60 (0.82)	4.87 (0.57)
Usage	6.58 (0.80)	6.62 (0.50)

Note: Descriptive statistics are for key outcome and predictor variables by technological conditions computer and iPad, with a sample size $n = 26$, $n = 29$, respectively.

Table 2.

Correlations matrix and their significance (p-value in parenthesis) between key variables.

	Platform Condition	Comprehension	Mental Workload	Attitudes
Comprehension	0.08 (0.55)			
Mental Workload	-0.07 (0.62)	-0.51 (< 0.001)		
Attitudes	0.20 (0.15)	0.04 (0.75)	0.04 (0.76)	
Usage	0.07 (0.60)	-0.23 (0.09)	0.18 (0.19)	0.27 (0.05)

Note: Correlation matrix was for key outcome and predictor variables with sample size $n = 55$. Only one significant correlation was found between comprehension and mental workload.

Figure 1. Results of Univariate Analysis of Comprehension Scores by Conditions
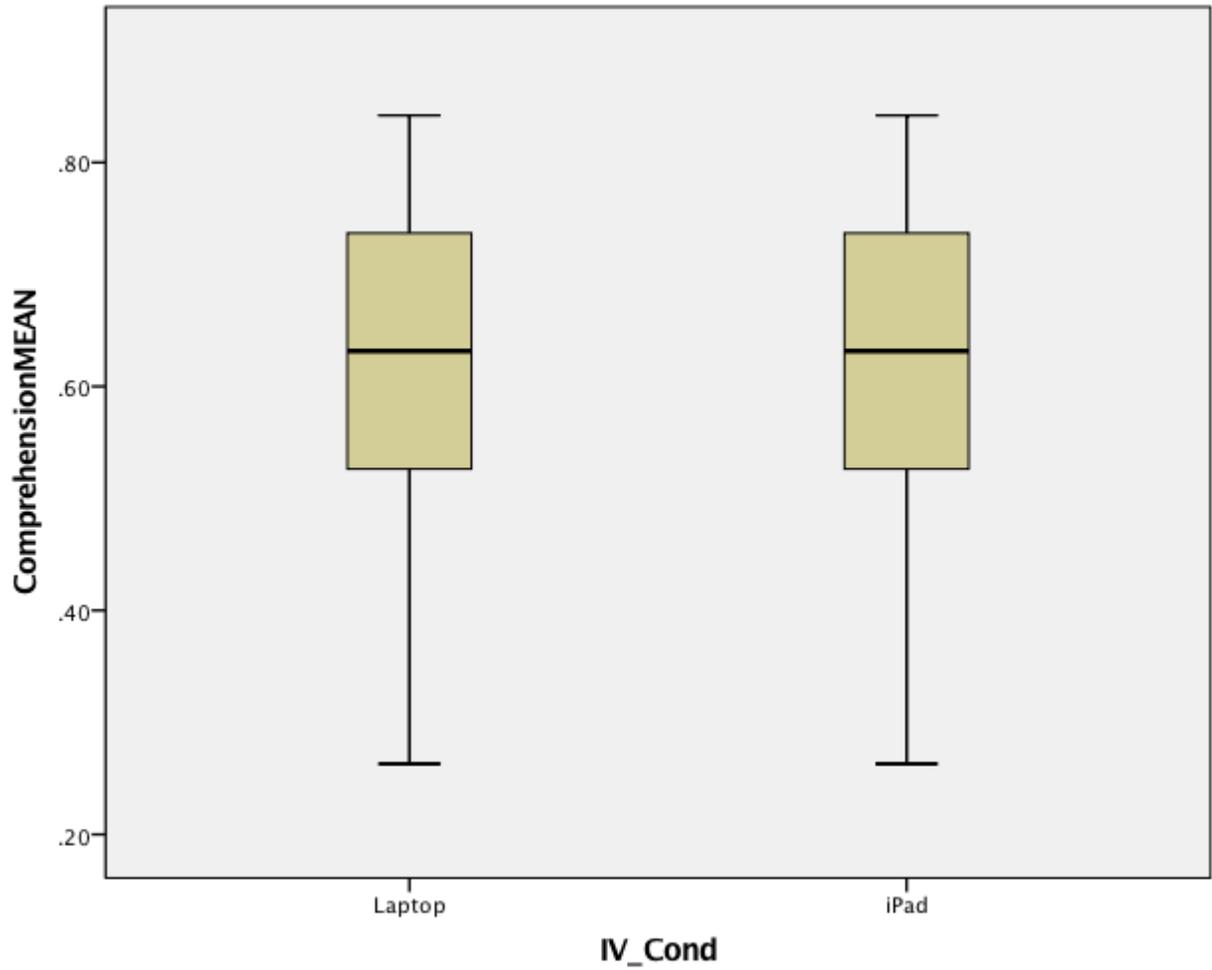
Figure 1. Side-by-side boxplots of reading comprehension scores by technological platform condition.

Figure 2. Plot of Mental Workload by Comprehension Scores
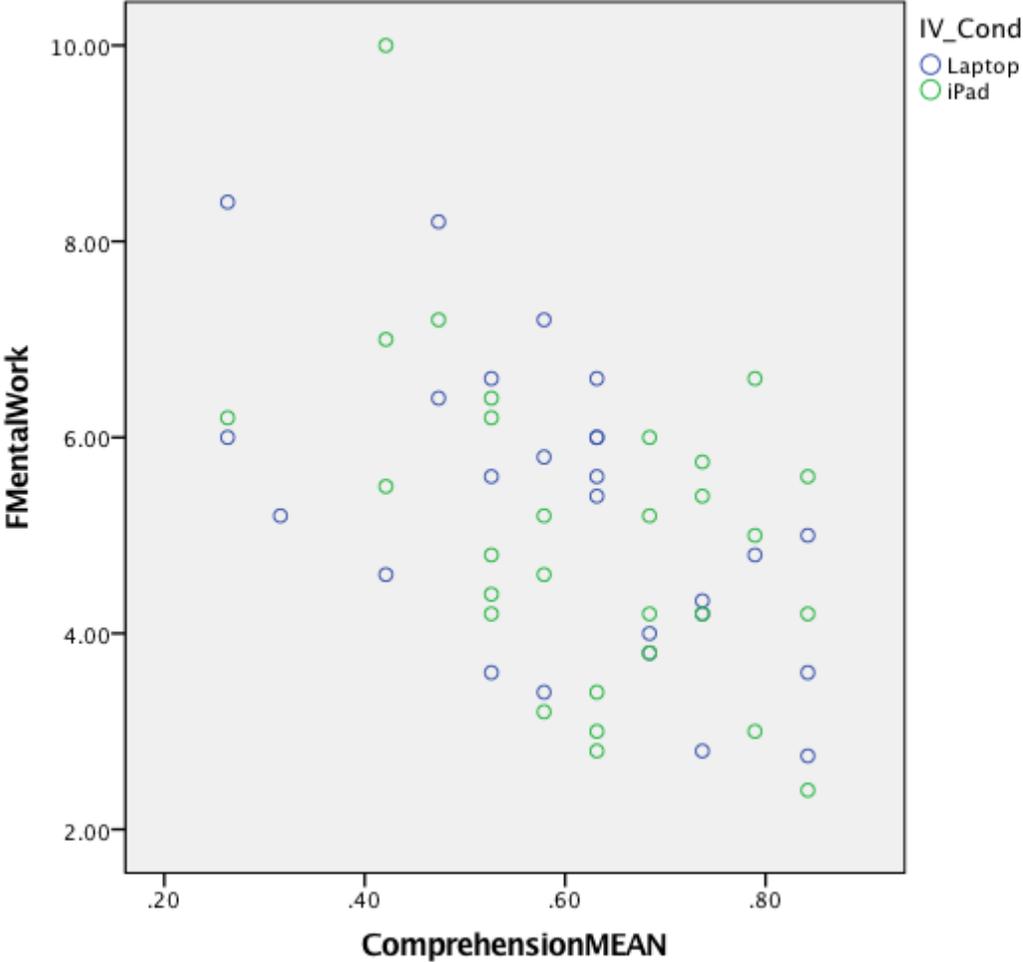
Figure 2. Bivariate scatterplot of reading comprehension scores by reported mental workload, separated by technological platform condition.

Figure 3. Plot of Attitudes Towards Technology by Comprehension Scores
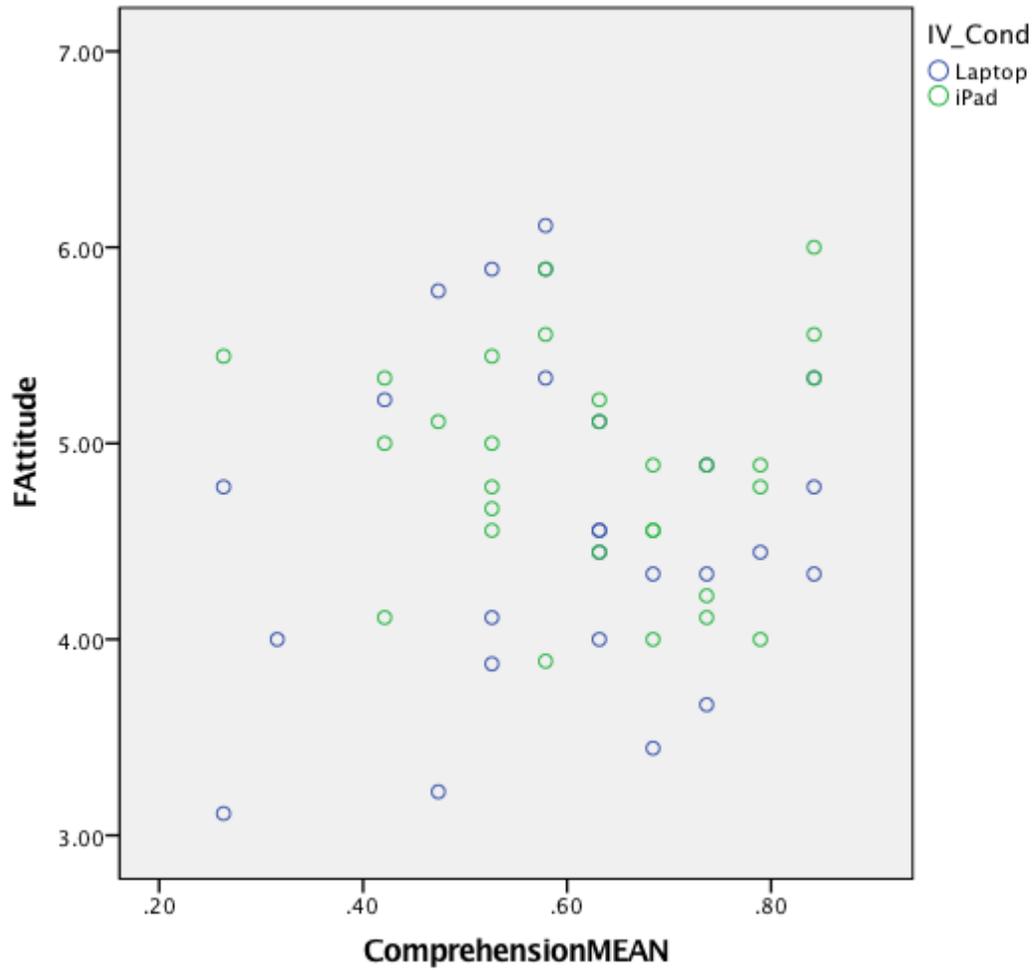
Figure 3. Bivariate scatterplot of reading comprehension scores by attitudes towards technology, separated by technological platform condition.

Figure 4. Plot of Usage of Technology by Comprehension Scores

Figure 4. Bivariate scatterplot of reading comprehension scores by frequency of technology usage, separated by technological platform condition.

Appendix C

NASA-TLX Mental Workload Rating Scale

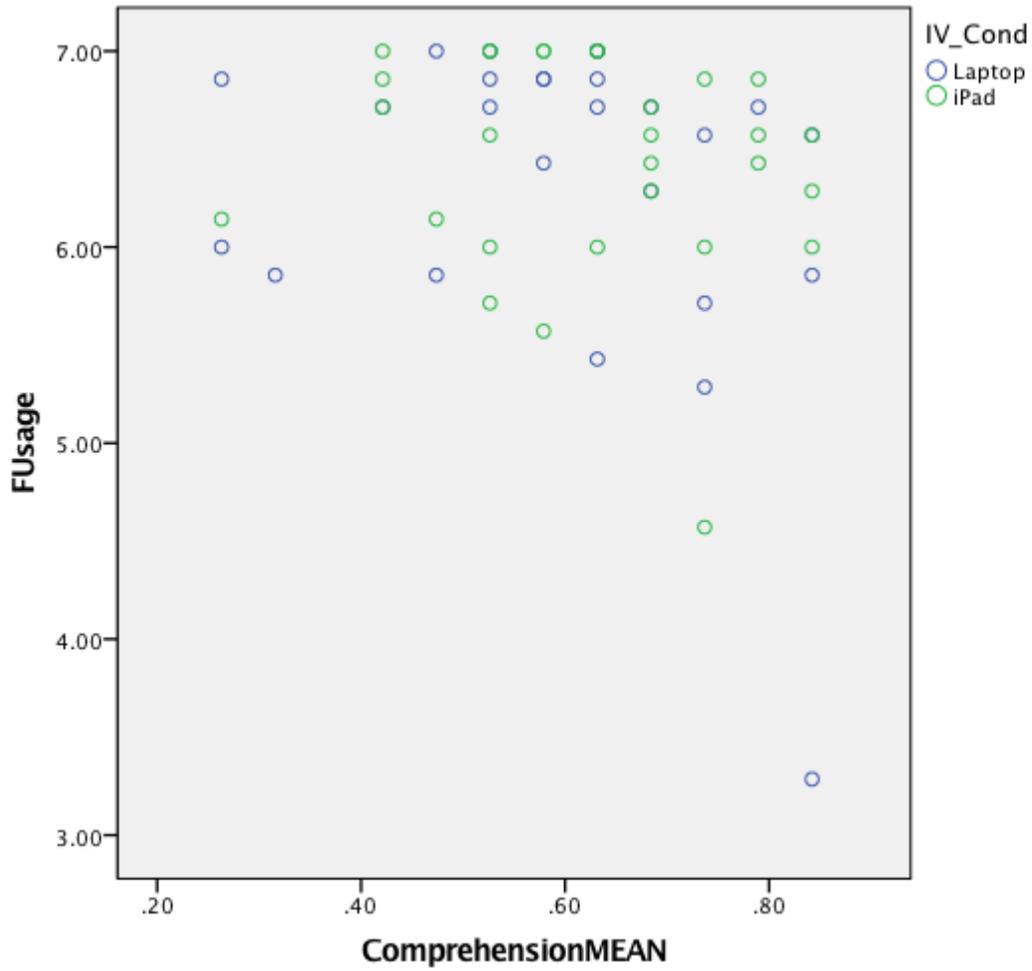Please place an "X" along each scale at the point that best indicates your experience with the display configuration.

Mental Demand: How much mental and perceptual activity was required (e.g., thinking, deciding, calculating, remembering, looking, searching, etc)? Was the mission easy or demanding, simple or complex, exacting or forgiving?

Low |⎿_⎿_⎿_⎿_⎿_⎿_⎿_⎿_⎿_⎿_⎿_⎿_⎿_⎿_⎿_⎿_⎿_⎿_⎿_⏌| High

Physical Demand: How much physical activity was required (e.g., pushing, pulling, turning, controlling, activating, etc.)? Was the mission easy or demanding, slow or brisk, slack or strenuous, restful or laborious?

Low |⎿_⎿_⎿_⎿_⎿_⎿_⎿_⎿_⎿_⎿_⎿_⎿_⎿_⎿_⎿_⎿_⎿_⎿_⎿_⏌| High

Temporal Demand: How much time pressure did you feel due to the rate or pace at which the mission occurred? Was the pace slow and leisurely or rapid and frantic?

Low |⎿_⎿_⎿_⎿_⎿_⎿_⎿_⎿_⎿_⎿_⎿_⎿_⎿_⎿_⎿_⎿_⎿_⎿_⎿_⏌| High

Performance: How successful do you think you were in accomplishing the goals of the mission? How satisfied were you with your performance in accomplishing these goals?

Low |⎿_⎿_⎿_⎿_⎿_⎿_⎿_⎿_⎿_⎿_⎿_⎿_⎿_⎿_⎿_⎿_⎿_⎿_⎿_⏌| High

Effort: How hard did you have to work (mentally and physically) to accomplish your level of performance?

Low |⎿_⎿_⎿_⎿_⎿_⎿_⎿_⎿_⎿_⎿_⎿_⎿_⎿_⎿_⎿_⎿_⎿_⎿_⎿_⏌| High

Frustration: How discouraged, stressed, irritated, and annoyed versus gratified, relaxed, content, and complacent did you feel during your mission?

Low |⎿_⎿_⎿_⎿_⎿_⎿_⎿_⎿_⎿_⎿_⎿_⎿_⎿_⎿_⎿_⎿_⎿_⎿_⎿_⏌| High

Appendix D

Reformatted Media and Technology Usage and Attitudes Scale

Low Usage   High Usage

1	2	3	4	5	6	7
Never	Less than once a Month	Once a month	2-3 Times a Month	Once a Week	2-3 Times a Week	Daily

➢ **Please indicate how often you do use your device(s) to:**

1. Send, receive and check e-mails (not including spam or junk mail).   _____
2. Send or receive files   _____
3. Check for texts or messages   _____
4. Record videos or take pictures   _____
5. Use applications   _____
6. Search for information   _____
7. Browse the web   _____
8. Listen to music   _____
9. Check, comment, or post on social media   _____
10. Play games alone or with others   _____
11. Watch TV shows, clips, or movies   _____

1	2	3	4	5
Strongly Disagree	Disagree	Neither agree nor disagree	Agree	Strongly Agree

➢ **How much do you agree or disagree with the following statements:**

1. I feel it is important to be able to find information whenever I want online   _____
2. I feel it is important to be able to access the Internet any time I want   _____
3. I think it is important to keep up with the latest trends in technology   _____
4. I get anxious when I do not have my cell phone   _____
5. I get anxious when I do not have the Internet available to me   _____
6. I am dependent on my technology   _____
7. Technology will provide solutions to many of our problems   _____
8. With technology, anything is possible   _____
9. I feel I get more accomplished because of technology   _____
10. New technology makes people waste too much time   _____
11. New technology makes life more complicated   _____
12. New technology makes people more isolated   _____

References

Ackerman, R., & Lauterman, T. (2012). Taking reading comprehension exams on screen or on paper? A metacognitive analysis of learning texts under time pressure. *Computers in Human Behavior, 28*(5), 1816-1828. doi:10.1016/j.chb.2012.04.023

Agostinho, S., Tindall-Ford, S., Ginns, P., Howard, S., Leahy, W., & Paas, F. (2015). Giving Learning a Helping Hand: Finger Tracing of Temperature Graphs on an iPad. *Educational Psychology Review, 27*(3), 427-443. doi:10.1007/s10648-015-9315-5

Ayres, P., & Paas, F. (2012). Cognitive Load Theory: New Directions and Challenges (Vol. 26, pp. 827-832).

Bowman, L. L., Levine, L. E., Waite, B. M., & Gendron, M. (2010). Can Students Really Multitask? An Experimental Study of Instant Messaging while Reading. *Computers & Education, 54*(4), 927-931. doi:10.1016/j.compedu.2009.09.024

Bui, D. C., Myerson, J., & Hale, S. (2013). Note-Taking with Computers: Exploring Alternative Strategies for Improved Recall. *Journal of Educational Psychology, 105*(2), 299-309. doi:10.1037/a0030367

Calisir, F., & Gurel, Z. (2003). Influence of text structure and prior knowledge of the learner on reading comprehension, browsing and perceived control. *Computers in Human Behavior, 19*(2), 135-145. doi:10.1016/S0747-5632(02)00058-4

Carrier, L. M., Rosen, L. D., Cheever, N. A., & Lim, A. F. (2015). Causes, effects, and practicalities of everyday multitasking. *Developmental Review, 35*, 64-78. doi:http://dx.doi.org/10.1016/j.dr.2014.12.005

Chiu, C.-H., Wu, C.-Y., & Cheng, H.-W. (2013). Integrating reviewing strategies into shared electronic note-taking: Questioning, summarizing and note reading. *Computers & Education, 67*, 229-238. doi:10.1016/j.compedu.2013.04.015

Chua, Y. P., & Don, Z. M. (2013). Effects of computer-based educational achievement test on test performance and test takers' motivation. *Computers in Human Behavior, 29*(5), 1889-1895. doi:10.1016/j.chb.2013.03.008

Coiro, J. (2011). Predicting Reading Comprehension on the Internet. *Journal of Literacy Research, 43*(4), 352-392. doi:10.1177/1086296X11421979

Coiro, J., & Dobler, E. (2007). Exploring the Online Reading Comprehension Strategies Used by Sixth-Grade Skilled Readers to Search for and Locate Information on the Internet. *Reading Research Quarterly, 42*(2), 214-257. doi:10.1598/RRQ.42.2.2

Commission, I. T. (2004). International guidelines on computer-based and internet-delivered testing.

Dumont, R., Viezel, K. D., Kohlhagen, J., & Tabib, S. (2014, 2014/09//). A review of Q-interactive assessment technology. *Communique, 43,* 8+.

Eyyam, R., & Yaratan, H. S. (2014). Impact of use of technology in mathematics lessons on student achievement and attitudes. *Social Behavior and Personality: an international journal, 42*(SI), S31.

Flewitt, R., Kucirkova, N., & Messer, D. (2014). Touching the virtual, touching the real: iPads and enabling literacy for students experiencing disability. *Australian Journal of Language & Literacy, 37*(2), 107-116.

Flewitt, R., Messer, D., & Kucirkova, N. (2015). New directions for early literacy in a digital age: The iPad. *15*(3), 289-310. doi:10.1177/1468798414533560

Foroughi, C. K., Werner, N. E., Barragán, D., & Boehm-Davis, D. A. (2015). Interruptions Disrupt Reading Comprehension. *Journal of Experimental Psychology: General, 144*(3), 704-709. doi:10.1037/xge0000074

Hutchison, A., Beschorner, B., & Schmidt-Crawford, D. (2012). Exploring the Use of the iPad for Literacy Learning. *Reading Teacher, 66*(1), 15-23. doi:10.1002/TRTR.01090

Ie, A., Haller, C. S., Langer, E. J., & Courvoisier, D. S. (2012). Mindful multitasking: The relationship between mindful flexibility and media multitasking. *Computers in Human Behavior, 28*(4), 1526-1532. doi:10.1016/j.chb.2012.03.022

Jodie, W., & Dennie, S. (2012). From Socrates to Satellites: iPad Learning in an Undergraduate Course. *Creative Education, 03*(05), 643. doi:10.4236/ce.2012.35094

Karr-Wisniewski, P., & Lu, Y. (2010). When more is too much: Operationalizing technology overload and exploring its impact on knowledge worker productivity. *Computers in Human Behavior, 26*(5), 1061-1072. doi:10.1016/j.chb.2010.03.008

Kauffman, D. F., Zhao, R., & Yang, Y.-S. (2011). Effects of Online Note Taking Formats and Self-Monitoring Prompts on Learning from Online Text: Using Technology to Enhance Self-Regulated Learning. *Contemporary Educational Psychology, 36*(4), 313-322. doi:10.1016/j.cedpsych.2011.04.001

Kim, D.-H., & Huynh, H. (2008). Computer-Based and Paper-and-Pencil Administration Mode Effects on a Statewide End-of-Course English Test. *Educational and Psychological Measurement, 68*(4), 554-570. doi:10.1177/0013164407310132

Kolakowski, N. (2011). Amazons Kindle EBooks Outselling Paper Books 792500. *eWeek*.

Larson, L. C. (2010). Digital Readers: The Next Chapter in E-Book Reading and Response. *Reading Teacher, 64*(1), 15-22. doi:10.1598/RT.64.1.2

Madden, M., Lenhart, A., Duggan, M., Cortesi, S., & Gasser, U. (2013). Teens and Technology 2013. *Pew Research Center's Internet & American Life Project., Washington, DC*.

Margolin, S. J., Driscoll, C., Toland, M. J., & Kegler, J. L. (2013). E-readers, Computer Screens, or Paper: Does Reading Comprehension Change Across Media Platforms? *Applied Cognitive Psychology, 27*(4), 512-519. doi:10.1002/acp.2930

Marmarelli, T., & Ringle, M. (2011). The Reed College iPad study.

Mavri, A., Loizides, F., & Souleles, N. (2014). A case study on using iPads to encourage collaborative learning in an undergraduate web development class. *In First International Conference on the use of iPads in Higher Education 2014.*

Mayes, D. K., Sims, V. K., & Koonce, J. M. (2001). Comprehension and workload differences for VDT and paper-based reading. *International Journal of Industrial Ergonomics, 28*(6), 367-378. doi:http://dx.doi.org/10.1016/S0169-8141(01)00043-9

McKenney, S., & Voogt, J. (2010). Technology and young children: How 4–7 year olds perceive their own use of computers. *Computers in Human Behavior, 26*(4), 656-664. doi:10.1016/j.chb.2010.01.002

Mead, A. D., & Drasgow, F. (1993). Equivalence of Computerized and Paper-and-Pencil Cognitive Ability Tests: A Meta-Analysis. *Psychological Bulletin, 114*(3), 449-458. doi:10.1037/0033-2909.114.3.449

Piaw, C. Y. (2012). Replacing Paper-based Testing with Computer-based Testing in Assessment: Are we Doing Wrong? *Procedia - Social and Behavioral Sciences, 64*, 655-664. doi:10.1016/j.sbspro.2012.11.077

Rockinson- Szapkiw, A. J., Courduff, J., Carter, K., & Bennett, D. (2013). Electronic versus Traditional Print Textbooks: A Comparison Study on the Influence of University

Students' Learning. *Computers & Education, 63*, 259-266. doi:10.1016/j.compedu.2012.11.022

Rosen, L. D., Whaling, K., Carrier, L. M., Cheever, N. A., & Rokkum, J. (2013). The Media and Technology Usage and Attitudes Scale: An empirical investigation. *Computers in Human Behavior, 29*(6), 2501-2511. doi:10.1016/j.chb.2013.06.006

Rosenfield, M., Jahan, S., Nunez, K., & Chan, K. (2015). Cognitive demand, digital screens and blink rate. *Computers in Human Behavior, 51, Part A*, 403-406. doi:http://dx.doi.org/10.1016/j.chb.2015.04.073

Sawicka, A. (2008). Dynamics of cognitive load theory: A model-based approach. *Computers in Human Behavior, 24*(3), 1041-1066. doi:http://dx.doi.org/10.1016/j.chb.2007.03.007

Schaffhauser, D. (2012). You May Now Open Your Test Tablets... *T H E Journal, 39*(7), 16-23.

Schwamborn, A., Thillmann, H., Opfermann, M., & Leutner, D. (2011). Cognitive load and instructionally supported learning with provided and learner-generated visualizations. *Computers in Human Behavior, 27*(1), 89-93. doi:10.1016/j.chb.2010.05.028

Selwyn, N. (1997). Students' Attitudes toward Computers: Validation of a Computer Attitude Scale for 16-19 Education. *Computers & Education, 28*(1), 35-41.

Shashaani, L., & Khalili, A. (2001). Gender and computers: similarities and differences in Iranian college students' attitudes toward computers. *Computers & Education, 37*(3), 363-375. doi:10.1016/S0360-1315(01)00059-8

Smith, B., Caputi, P., & Rawstorne, P. (2000). Differentiating computer experience and attitudes toward computers: an empirical investigation. *Computers in Human Behavior, 16*(1), 59-81. doi:10.1016/S0747-5632(99)00052-7

Swanson, C. B. (2006). Tracking U.S. trends. *Education Week's Technology Counts, 25(35)*, 50-53.

Tsai, C.-C., Lin, S. S. J., & Tsai, M.-J. (2001). Developing an Internet Attitude Scale for high school students. *Computers & Education, 37*(1), 41-51. doi:10.1016/S0360-1315(01)00033-1

Waters, J. K. (2010). Enter the iPad (or not?): Apple's new table computer has earned raves for its design, portability, and dynamic apps, but is it any better than the netbooks and laptops now fueling school computing programs? Depends who you ask.(1-to-1 computing)(Cover story). *T H E Journal (Technological Horizons In Education), 37*(6), 38.

Wu, Y.-T., & Tsai, C.-C. (2006). University students' Internet attitudes and Internet self-efficacy: a study at three universities in Taiwan. *Cyberpsychology & behavior : the impact of the Internet, multimedia and virtual reality on behavior and society, 9*(4), 441.

Zambarbieri, D., & Carniglia, E. (2012). Eye movement analysis of reading from computer displays, eReaders and printed books. *Ophthalmic and Physiological Optics, 32*(5), 390-396. doi:10.1111/j.1475-1313.2012.00930.x