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Technology and Reading Performance in the Middle-School Grades: A Meta-Analysis with Recommendations for Policy and Practice[1]

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The results of a meta-analysis of 20 research articles containing 89 effect sizes related to the use of digital tools and learning environments to enhance literacy acquisition for middle school students demonstrate that technology can have a positive effect on reading comprehension (weighted effect size of 0.489). Very little research has focused on the effect of technology on other important aspects of reading, such as metacognitive, affective, and dispositional outcomes. The evidence permits the conclusion that there is reason to be optimistic about using technology in middle-school literacy programs, but there is even greater reason to encourage the research community to redouble its efforts to investigate and understand the impact of digital learning environments on students in this age range and to broaden the scope of the interventions and outcomes studied.

Resúmen

En este estudio se reportan los resultados del meta-análisis realizado en 20 investigaciones, las cuales contienen 89 medidas de efectos relacionados con el uso de herramientas digitales y medios de aprendizaje para mejorar la adquisición de lecto-escritura en estudiantes de escuela media. Los resultados indican que la tecnología puede tener un efecto positivo en la comprensión de lectura (medida de efecto de 0.489). Pocas investigaciones se han enfocado en los efectos de la tecnología en otros aspectos importantes de la lectura, tales como metacognición, afectividad y disposición. Los resultados de este estudio permiten concluir que hay razones para ser optimistas acerca del uso de la tecnología para la enseñanza de lecto-escritura en la escuela media, y que hay razones para: (a) estimular a la comunidad investigativa a multiplicar los esfuerzos para estudiar y entender el impacto que tienen los medios digitales en los estudiantes de esta edad y (b) ampliar el enfoque de las intervenciones y los resultados estudiados.

科技手段与中学阶段的阅读表现：结合理论与实践的整合分析

摘要

本研究在对20份研究文献的整合分析后发现了89个效应值，这些效应值与加强中学生语言获得的数字工具和学习环境相关。这一发现显示科技手段对阅读理解具有正面效应（权重效应值为0.489）。以往研究很少关注科技手段在阅读的某些重要方面的效应，比如元认知，情感和倾向性结果。本研究的结论为我们提供了一个充分的理由去乐观地看待中学语言教学中的科技手段使用。然而，更需要我们去做的是以下两点：（1）鼓励研究团体深入调查并理解数字学习环境对本年龄阶段的学生的影响；（2）扩大干预和结果研究的范围。

Résumé

Cette étude présente les résultats d'une méta-analyse de 20 articles de recherche qui contiennent 89 tailles d'effet relatifs à l'utilisation des outils numériques dans l'environnement éducatif pour améliorer l'acquisition de la lecture-écriture parmi les élèves de collège. Les résultats montrent les effets positifs que peut avoir la technologie sur la compréhension des textes (taille d'effet de 0.489). Peu de recherche a été faite sur l'effet de la technologie sur d'autres aspects importants de la lecture, tels que les résultats méta-cognitifs, affectifs, et dispositionels. Les résultats de cette étude nous encouragent à rester positifs en ce qui concerne l'utilisation de la technologie dans les programmes de collèges. Cependant, il y a plusieurs raisons pour encourager la communauté de chercheurs à redoubler ses efforts pour examiner et comprendre l'impact de l'utilisation de la technologie numérique dans les classes des élèves de cet âge, et d'élargir les possibilités des interventions et des résultats étudiés.

BACKGROUND FOR THE META-ANALYSIS

Over the past several years, a great deal of attention has been given to the role of new technologies, such as multimedia and hypermedia, on learning (e.g., Cavanaugh, Gillian, Kromney, Hess, & Blomeyer, 2004; Waxman, Linn, & Michko, 2003; & Dynarski et al., 2007). The impact of new technologies on literacy acquisition and instruction is no exception to this trend. Increasingly, accumulating research evidence has begun to provide recommendations for reading policy and practice (Labbo & Reinking, 1999; Leu, 2002; Reinking, 2003).

For better or worse, most of the studies in this research corpus have addressed literacy or reading acquisition in the early years of schooling. To test the hypothesis that these technologies may be equally as important for older readers, particularly those who have not experienced great success in their school careers, we examined existing research about the impact of digital tools on the reading performance of middle-school students by conducting a meta-analysis of as many of the relevant experimental studies as met the standards for inclusion in this important summative effort.

The primary purpose of this work was to determine whether digital technologies can affect the acquisition of advanced reading skills, such as comprehension, metacognition, strategy use, and motivation and engagement. Another purpose was to identify, or at least to point in the direction of, substantive (i.e., topics or skills are being taught), technical, and contextual factors that might mediate or moderate effective interventions. The ultimate outcomes of this second purpose, we hoped, would be (a) a set of implications to guide policy makers in their quest to improve reading acquisition in these vexing middle-school years and (b) a menu of promising pathways to guide future research.

Evolving Relationship Between Literacy and Technology

Literacy and technology are two words that seem to be increasingly paired in today's world of research, practice, and policy. People often describe the need to become computer literate; authors write about digital literacy (and related terms such as visual literacy and media literacy) as one of the important new discourses in our schools; and research has investigated the role of technology in improving literacy acquisition and instruction.

The need to become computer literate is very real in the policy and practice of today's schools. The National Educational Technology Standards (NETS), for instance, have been developed to ensure that children are learning with technology and using digital tools to acquire knowledge in content areas (http://cnets.iste.org/). The International Reading Association suggested the following rights for students in a 2001 position statement on literacy and technology:

- Teachers who are skilled in the effective use of Information Communications Technology (ICT) for teaching and learning
- A literacy curriculum that integrates the new literacies of ICT into instructional programs
- Instruction that develops the critical literacies essential to effective information use
- Assessment practices in literacy that include reading on the Internet and writing using word-processing software
- Opportunities to learn safe and responsible use of information and communication technologies
- Equal access to ICT

Such goals and standards include not just attaining comfort with and knowledge of the machine but also related literacies including information literacy, visual literacy, digital literacy, new literacies, critical literacy, and media literacy (Holum & Gahala, 2001).

As one looks broadly at the interface of technology and literacy, perhaps most potentially rewarding for literacy educators is the role of technology in literacy acquisition and instruction, especially for primary grade populations. We know, for example, that electronic storybooks help improve student comprehension and motivation (Matthew, 1997; Doty, Popplewell, & Byers, 2001) and that they also provide immediate decoding feedback to students (Labbo & Kuhn, 1998; deJong & Bus, 2002; Cazet, 1998; Doty, Popplewell, & Byers, 2001).

In addition to electronic storybooks, teachers use software such as KidPix (Labbo, Eakle, & Montero, 2002), Hyperstudio, and Microsoft PowerPoint to help students learn to decode. Web sites such as *Hot Potatoes* (http://web.uvic.ca/hrd/halfbaked/) and *Enchanted Learning* (http://www.enchantedlearning.com/Home.html) provide cloze exercises and paragraph, sentence, and letter scramblers. PBS Kids & Sesame Street's *Letter of the Day* (http://pbskids.org/sesame/letter/) and Scholastic's *Letter Matc*h (http://teacher.scholastic.com/clifford1/flash/confusable/) provide activities at the letter level. Even Merriam-Webster's allegedly lexicographically-oriented Web site (http://www.m-w.com/) provides support for phonemic awareness and instruction. Finally, Leu & Kinzer (1999) have argued that (1) Internet activities, (2) Internet projects, (3) Internet inquiries, and (4) Internet workshops can lead to effective literacy instruction and reading comprehension.

Technology is also used for writing instruction; indeed, the interface of technology and writing is sufficiently sophisticated to have attracted both "best practice" syntheses as well as meta-analysis (Goldberg, Russell & Cook, 2003). The *Venn Diagram* website (http://www.venndiagram.com/), software tools such as Inspiration and Microsoft PowerPoint, and hardware such as Smartboards and Interactive Whiteboards provide students with opportunities to create visual displays such as concept maps to organize their writing. E-zines, or electronic magazines, not only provide current and authentic reading material for students; they also publish student work and thus act as an authentic audience for student writing. Electronic portfolios are providing ways for students to showcase their writing to teachers, other students, and parents.

Even simple word processors have tracking changes features where students can collaborate in their writing and thus receive scaffolding in their development. Blogs can provide online journaling space for students to write about their growing expertise or their daily observations (Ferdig & Trammell, 2004), and word searches, word games, and online dictionaries and thesauruses build students' vocabulary and confidence in language use. Students and teachers also find great writing practice using webquests and inquiry pages. Finally, students get writing practice through authentic projects such as Keypals, where they write with classrooms in different states or countries, and the Internet Project Registry, where classes can register their projects and collaborate with students from around the world.

Beyond reading and writing, technology has been used to increase access to images of and information about diversity in classrooms, both at the student level with projects like *I Love Languages* (http://www.ilovelanguages.com/) and *Say Hello to the World* (http://www.ipl.org/div/kidspace/hello/) and also at the instructor and preservice level with projects like CTELL (Teale, Leu, Labbo, & Kinzer, 2002) and *The Reading Classroom Explorer* (Ferdig, Roehler, & Pearson, in press). Technology has been used to give struggling readers access to scaffolding and individualized instruction through projects like *Technology-Enhanced Literacy Environment-Web* (TELE-Web; Zhao, Englert, Jones, Chen, & Ferdig, 2000). Computers, and even older media such as audio and video recorders, give students practice with spoken language. Free online archives provide reading material for both storytelling and literature classes. Finally, online journals, listservs, discussion forums, and associations provide continued professional development for the literacy instructor.

In short, we have witnessed a proliferation of applications of various sorts of technology for various populations of users from preschoolers to teachers. But have we conducted enough careful research in the technology education field to have reached a point of maturity sufficient to merit extensive reviews, such as best-evidence syntheses and meta-analyses of various aspects of technology tools?

We have certainly made those attempts in recent years, but with varying degrees of success. In recent years, Cavanaugh et al. (2004) provided evidence in their meta-analysis that distance education is as effective as face-to-face classroom instruction. Shachar & Neumann (2003) found that distance learners outperformed counterpart students in face-to-face classrooms in two thirds of the studies. In synthesizing the literature on teaching and learning with technology, Waxman et al. (2003) found technology had a consistently positive significant effect on student outcomes, a finding supported by others in this field (Kulik & Kulik, 1991; Kulik & Kulik, 1986).

Turning to the purview of the present study, there have been a few recent meta-analyses related to literacy and technology. Goldberg, Russell, and Cook (2003) synthesized 26 studies from 1992–2002 and found that the use of computers improved the quality and quantity of writing compared to classrooms without technology. They did find mixed results, however, for revision behaviors. Torgerson, Porthouse, and Brooks (2003) found a modest but not statistically reliable benefit for computer-assisted instruction for literacy acquisition of imprisoned adults. Finally, Torgerson and Elbourne (2002) completed a meta-analysis on the effects of information communications technology on spelling, finding what they characterize as a modest but not statistically significant effect favoring technology in the teaching of spelling. The National Reading Panel (2000) began its work with a clear intention of conducting a meta-analysis of the effect of technology on reading achievement, but the scholars who conducted the review decided that the paltry yield of appropriate experimental studies that emerged from their extensive review merited only a best-evidence synthesis. In short, there were too few studies meeting their design standards to justify a meta-analysis. Nonetheless, in examining the effect of technological learning environments and tools on reading achievement descriptively, they concluded that, while the data base was too sparse and too broadly distributed over populations and emphases to permit definitive conclusions, they saw some merit for word processing as an indirect aid to comprehension, some evidence for the efficacy of speech to print phonics programs, and a great deal of promise for the future.

On the specific question of the empirically established relationships between literacy and technology, Leu (2000) has suggested that our scholarship to date warrants at least three distinct conclusions:

(1) Technology is *transformative*, changing the nature of literacy (see also Reinking, 1998);
(2) the relation between literacy and technology is *transactional* (see Bruce, 1997); and
(3) technology is *deictic*, which means that it will change rapidly in response to environmental forces.

Even the strongest proponents of employing technology to enhance literacy acknowledge the alarmingly low number of published research studies investigating technology and literacy (Leu, 2006; Kamil & Lane, 1998). Clearly either more research has to be done, or we need a better approach to identifying and analyzing relevant existing research. The current endeavor is predicated on the assumption that, although we may well need more and better research, it is time to take stock of what we do know, if for no other reason than to highlight gaps to guide the field in future scholarly efforts. If the effects we do find are truly powerful, even though limited in scope, we should publicly acknowledge and use what we do know and can recommend to policymakers with confidence.

Concerns About Literacy, Technology, and Adolescents

No Child Left Behind (NCLB) funds reading programs (Reading First) that focus primarily on Prekindergarten through Grade 3; however, the NCLB Act of 2001 (NCLB, 2002) also requires students in Grades 4 through 12 make adequate yearly progress toward meeting state reading standards. In addition, the Reading First provision of NCLB dictates that students who are not making adequate progress in the middle-school years be offered research-based interventions to accelerate their learning. Finally, even though the lion's share of the resources for improving reading in the context of current policy goes to the primary grades, the rhetoric about the need for focusing greater attention and resources on adolescent literacy has been steadily mounting for the past few years.

Several professional organizations, in fact, have championed this shift in attention. For example, the National Reading Conference (NRC) commissioned a white paper on Effective Literacy Instruction for Adolescents (Alvermann, 2001) that explicitly acknowledges the complexities of reading in relation to writing and oral language in an array of 21st-century media environments, including, of course, print. The International Reading Association, in its Position Statement on Adolescent Literacy (2002), echoed this perspective by emphasizing the importance of (a) ensuring access to a wide variety of reading materials, (b) building skills and desire to read complex materials, (c) modeling and giving explicit instruction, and (d) developing an understanding of the complexities of individual adolescent readers.

While our empirical knowledge may be weak, individuals have used theoretically-based arguments, grounded in case studies, to draw conclusions about the degree to which technology tools can and do support literacy teaching and learning for adolescents. For instance, although Alvermann (2001) cites little empirical research on the topic generally, and even less that applies specifically to instruction at the middle and high school levels, she, along with others, provides relevant examples to illustrate how adolescents are making valuable reading-writing connections in their bid to communicate in a computer-mediated world (e.g., Beach & Bruce, 2002; Beach & Lundell, 1998; Horney & Anderson-Inman, 1994).

Other work suggests that American youth are turning more and more toward the Internet as their primary textbook and spend more time with media than in any other single activity (Gee, 2003; Lenhart, Simon, & Graziano, 2001; Levin & Arafeh, 2002). Levin and Arafeh (2002) found, for example, that 71% of students pointed to the Internet as their primary resource for completing homework assignments. These same students actually regarded the Internet as more relevant to their daily lives than other forms of information, a finding suggesting that schools are woefully slow on the Internet uptake. We agree with O'Brien (in press) that the widespread use of the Internet and other digital tools among youth requires educators to facilitate students' experiences with digital literacy tools in school. What we are less certain about, and certainly less knowledgeable about, is the particular focus that facilitative support should take. Indeed, the fact that so many scholars of adolescent literacy resort to compelling cases to support their policy and practice recommendations about literacy underscores the need for precisely the sort of synthesis we have undertaken.

STUDY METHODOLOGY

Context for a New Technology/Literacy Research Synthesis

Because our work was commissioned by a regional laboratory under contract with the Institute of Education Sciences, it is important for readers to understand the influence of that context on the mission and scope of our work, as well as the methodology we employed. At the time our project was commissioned by NCREL, under funding approved by program managers in the Institute for Educational Science, both NCREL's Centers for Technology and Literacy already were engaged in a collaborative effort intended to produce and disseminate information resources supporting improved literacy practices for middle school students. This activity was being undertaken by NCREL in response to assessed regional priorities in their seven-state region and in response to a range of national initiatives that raised concerns about the importance of continuing literacy instruction beyond the elementary grades, especially for students at the middle and high school levels (e.g., Alvermann, 2001; International Reading Association, 2001).

TABLE 1
Literature Search, Screening and Selection Procedures

Process Step	*Purpose*	*Criterion/Standard*	*Results/No. Sources*
Initial literature review	Identify largest possible number of sources	See lists of journals, databases, and search engines employed	204 initial sources
First screening	Qualification based on methodology & rigor	Adapted WWC Standards (See Appendix A)	105
Second screening	Grade level qualifications	Grades 6–8	72
Third screening	Content qualification	Related to "reading"/ SUBJECT CODING	45
Fourth screening	Technology qualification	I.T. integrated instructional delivery/TECHNOLOGY CODING	38
Final study corpus	Repeat prior screenings/ review newly discovered sources	WWC and all prior screening criteria apply	20

To narrow the proposed research topic from "the effectiveness of technology on student achievement in literacy," as defined by Learning Point Associates' (LPA) approved and annually updated 2004 "scope of work," NCREL staff members reviewed existing literature review initiatives undertaken by the What Works Clearinghouse (WWC) to avoid duplication of efforts already undertaken by the WWC's developers. As a result, our study methodology was strongly influenced by work already underway at the What Works Clearinghouse. The WWC had already developed a comprehensive literature review process and standards intended for use in evaluating the strength of research-based evidence documenting the effectiveness of educational interventions. Approval of our new research synthesis project by IES program officers managing the NCREL contract was made contingent upon orthodox use of WWC standards for selection and screening purposes. We subsequently devised and employed selection and screening procedures based on the most current "WWW Study Review Standards" available to us at that time (the adapted WWC rubric appears in Appendix A). Those included the *WWC Evidence Standards* (http://www.w-w-c.org/reports/study_standards_final.pdf) and the process outlined by the WWC's "Study Design and Implementation Assessment Device" *(version 1.1)*. Our adaptation of the WWC's selection and screening criteria is illustrated in Table 1.

Inclusion Criteria

A study was included in this meta-analysis if it met the following criteria:

- Was subjected to a peer review process. This excluded studies such as doctoral dissertations, conference presentations, and unpublished reports, but it did include prepublication project reports that were peer-reviewed.
- Included students in the middle grade school levels (6th, 7th, and 8th grades). Those studies that only reported results on these levels were labeled "right on target." There were studies that included earlier or later grades along with the middle level grades. Where possible, we only used the effect size (ES)[2] data from the target grade levels. Occasionally, when data could not be disaggregated (e.g., Grades 5–7 were lumped together), we spilled over into adjacent grade levels.
- Used technology as the independent or moderating variable in the examination of reading skills.
- Reported outcomes assessing the impact of a treatment on reading comprehension, metacognition, strategy use, and/or motivation.
- Used an experimental or quasi-experimental design, including pretest-posttest designs.
- Reported sufficient statistics to permit the calculation of effect sizes.
- Was published between 1988 and 2005. The time period was decided upon to address articles that had not been reviewed in previous and broader meta-analyses on the relationship between technology and reading processes.

Location and Selection of Publications

In an effort to be inclusive (and to take advantage of work conducted around the world), the search process was purposefully broadened to include studies from as many countries, languages, and cultural ranges as possible. We searched and included studies from many geographical areas as well as studies written in Spanish (one of the authors is a native Spanish speaker). It should be noted that most of the international journals consulted publish in English. We found a few candidate studies in Spanish, one of which survived into the final pool; many candidates and several finalists came from research conducted outside North America.

Identifying bibliographic sources. An exhaustive search of databases, journals, Web sites, and bibliographic resources was carried out for studies that could even plausibly meet the established inclusion criteria. Five main searches were completed. First, drawing on various combinations of keywords (Appendix B), web searches were performed using such search engines as Google, Google Scholar, Yahoo, Metacrawler, Search.com, AskJeeves, AltaVista, and Lycos. Second, similar keywords were used to systematically search academic and educational databases (Appendix C). The third search method was to examine

[2]We use the word, effect size, and the acronym, ES, interchangeably throughout the article.

abstracts in 79 educational technology, special education, psychology, literacy, and reading journals both in print and electronic modes, as not all journals or issues are available electronically (Appendix D). Fourth, in an effort to cover other cultural and linguistic ranges, abstracts in 34 relevant international journals were searched (Appendix E). Finally, Web sites of several reading and education professional organizations and research institutes were browsed for studies. Examples of such sites are the various regional educational laboratories, the Center for Research on Evaluation, Standards, and Student Testing, the research centers for various states departments of education, the RAND Corporation, and federal institutes such as the National Institute of Child Health and Human Development.

Focusing on populations and topics. Consistent with our mission and our collective professional curiosity, our synthesis set out to apply meta-analysis to answer questions about five key areas in order to provide information essential to improved reading performance for adolescents: the impact of digital literacy tools on middle-school students in the following areas:

- strategy use
- metacognition
- reading motivation
- reading engagement
- reading comprehension

We sought studies that attempted to both improve and measure progress in one or more of these areas. We defined digital literacy tools broadly to include a wide range of the use of media forms—images, video and audio clips, hypertext, hypermedia, Web pages, learning environments, and particular formats of presenting information for student learning. Of particular interest were the media forms of hypertext, hypermedia, and Web pages; we hoped that we would find a substantial body of experimental and quasi-experimental work examining these particular forms. This focus was strategic and intentional. We knew that the concepts of hypertext and hypermedia are considered crucial to understanding the interactions between reader and text in a multimedia environment. Also, conventional wisdom about the effect of hypertext and other media on reading performance, especially in content area reading, is optimistic and enthusiastic (Vacca & Vacca, 2007). We wanted to know whether such a high level of enthusiasm is supported by the available evidence.

Screening and Selecting the Study Final Corpus

The initial strategy for this search process was extensive rather than intensive. The goal was to identify the maximum number of studies and articles that met or even came close to meeting the inclusion criteria. "Backward mapping" was also used; we consulted the references at the end of target articles for potential other studies. Finally, literacy and technology experts (operationally defined as individuals whose works we encountered searching the literature), both in the United States and abroad, were contacted to solicit advice and information on studies not found in the searches or in the journals examined.

After an initial search, 204 full-text candidate articles or reports were located. During the first screening, study candidates were evaluated for inclusion after a screening that employed an adapted version of the WWC screening protocol. In all, 204 articles were subjected to 4 successive screenings considering these 4 selection criteria: (1) research methodology and rigor, (2) grade levels of participating students, (3) content considerations; and (4) technology qualification.

First, the type of study was examined to determine if it was an experimental study, quasi-experimental study, a natural experiment, a literature review, a correlation study, or a qualitative study. During the first screening, we employed an adapted version of the WWC screening instrument and accepted only the most methodologically rigorous experimental or quasi-experimental studies as being acceptable for inclusion in our meta-analysis. (See Appendix A. Adapted WWC Study Review Rubric.)

During the second screening, the grade level of subjects was scrutinized. Only studies having subjects in Grades 6–8 were accepted for analysis with the study corpus. During the second screening, we discovered one study accepted for review that had an overlap in grade levels or a "spillover" from participants in grades other than 6–8. Ligas (2002) included participating students from grades 3–8, leaving open the possibility of grade overlap or "spillover" into grades 3, 4, and 5. In this case, the study team decided to include the Ligas study but to code only the results from grades 6–8. This singular coding decision eliminated any possibility of data contamination from spillover effects.

During the third screening, articles were included if the content of the study was at least partially related to reading (rather than writing, language arts, or some other content interest), in terms of the intervention and the outcome. Finally, articles were coded for the *use of the technology* in the study. Articles were not included in the meta-analysis if technology was not used or if the use of technology was incidental.

During the third and fourth screenings, considering both literacy and technology content, we began coding variables for the meta-analysis based on procedures we adapted for our study from coding protocols developed by Waxman and his colleagues (2003) for LPA. During the process of applying these criteria, which included the computation of effect sizes for each dependent measure, the set of articles was trimmed to the 20 that eventually were used in the meta-analysis.

In the end, several studies passed the methodological, grade-level, content, and technology screenings but ultimately could not be used because they did not have sufficient data to compute the effects sizes or reported results without control or treatment statistics. These studies were discarded after attempted coding failed because study team members discovered that these seemingly acceptable qualitative studies apparently had little or no data reported to support quantifying the study variables.

To summarize, each of the candidate studies was read by at least two of the five authors of the report. When we applied the four successive levels of screening criteria, the final corpus was ultimately reduced from a total of 204 possible candidates to only 20 studies finally coded for the meta-analysis. These steps are detailed in Table 1, and summaries of the 20 studies that were finally screened, selected and coded for this study are available in Appendix F.[3]

SELECTING AN APPROPRIATE METRIC

To obtain effect sizes, the quantitative results from individual studies were transformed into a standardized difference between the treatment and the control group on a given measure. We calculated effect sizes by taking the mean performance difference between the group that received technology experimental treatment and the control group and dividing it by a pooled standard deviation. Because it has been well documented that effect-size index tends to be upwardly biased when based on small sample sizes, Hedges' (1981) correction was applied to compensate for the modest size of our final study corpus. The Hedges correction uses an inverse variance weight to give more weight to studies with larger sample sizes. We employed the Hedges "g" statistic, a weighted effect-size estimate, in all subsequent analyses. Two different effect-size calculation methods were utilized depending on the summary statistics reported within the individual research studies: posttest means and standard deviations ($n = 15$) and between-groups independent t test ($n = 4$). Effect sizes were computed using formulas provided by Lipsey & Wilson (1993); in a few instances, we used t or F test statistics to infer appropriate values.

Selecting a Statistical Treatment Model

The statistical models for meta-analysis are broadly classified into two types: fixed effects and random effects. Fixed-effects models generalize to a hypothetical population of studies, from which one assumes to have drawn a random sample. Random-effects models generalize to a population of subjects. The models differ in the way they treat the variability of the results between the studies.

[3]See Pearson et al. (2005) for the complete Waxman-derived codebook and for an inclusive bibliography detailing the 204 studies that were reviewed, screened, and disqualified for consideration in our final study corpus.

The fixed-effects model treats variability as exclusively due to random variation; thus, if all the studies were infinitely large, they would give identical results. The random-effects model assumes a different underlying effect for each study and takes this into consideration as an additional source of variation. In general, random-effects models are more conservative because they result in wider confidence intervals than the fixed-effects model. In all of our analyses, we used the random-effects model particularly due to the small number of studies and the related issues of homogeneity.

Three types of data analyses were performed:

1. For each study, an independent set of effect sizes were first extracted, weighted, and then aggregated. Using the combined effect size extracted from each study, an overall effect size across studies was calculated and tested for statistical significance.
2. Analyses were performed to investigate heterogeneity and publication bias of the effect sizes. We utilized homogeneity testing and forest plot depiction as our statistical tools for this analysis.
3. Based on our substantive interests in this area of research, we conducted several comparisons of the extent to which study features (e.g., population served or instructional focus) moderated the effect on outcome measures. For these comparisons, we used the total of 89 effect sizes. In doing each of these specific comparisons, which are the counterpart of post-hoc tests simple effects tests in analysis of variance, we computed a Q statistic to test the difference between effect sizes aggregated for the levels of a given variable (after Lipsey & Wilson, 2001).

We used the weighted average, as recommended in the statistical literature, to give more weight to larger studies with less random variation than to smaller studies. The method we used was the inverse variance method where the weights are equal to the inverse of each study's estimated effect size.

Computing Effect Sizes from Correlated Designs

A consistently vexing question for those who undertake meta-analyses is how to compute effect sizes when there are correlated designs such as matched groups, repeated measures, within-subjects factorial design, and single subject, among others. In these designs, there are two possibilities to compute the effect size for a study. One possibility is to use the original standard deviations for the means of two groups (treatment and control). Another possibility is to take into account the correlation between two scores. If we follow the second possibility the calculated effect will be larger than the first possibility (at least when the correlation exceeds 0.5).

The work done by Dunlop, Cortina, Vaslow and Burke (1996) and Morris and DeShon (2002) convincingly argues that original standard deviations should be used to compute ES for correlated designs. These authors argued and demonstrated that, if the pooled standard deviation is corrected for the amount of correlation between the measures, then the ES estimate will be an overestimate of the actual ES. In our meta-analysis, we did use both approaches and found that when the effect sizes were calculated by taking the correlations into account, none of the major findings and conclusions were altered.

RESULTS AND DISCUSSION

Descriptive Results

One of the more interesting results of our analysis was that we were able to locate data allowing us to address adequately only one of the five areas of reading about which we sought empirical evidence: comprehension. We found only two studies that provided outcome measures for strategy use (Salomon et al., 1989; Reinking, 1988). In the Salomon study, the effect sizes were "off the charts" in favor of the technological training over the control group, which received no metacognitive emphasis. By contrast, the effect sizes in the Reinking study were inconsequentially in favor of the control group on strategy use (in the −0.05 to −0.10 range).

Overall, we were unable to separate strategy use from metacognition in the 20 studies we screened, selected, and coded. It seems that, in the studies available up to the date our literature search concluded, strategy use is seen as being inherently metacognitive either as an outcome or as the focus of an intervention. In the final analysis, we decided to group strategy use and metacognition together for the purpose of analyzing and interpreting our findings. Only four studies selected for inclusion in the study corpus "mentioned" motivation, and, of those, only two (Kramarski, 2000; Reinking, 1988) included measures of it. Engagement was reported as a qualitative outcome and then only by a very few authors. This construct was used by those few study authors to describe the apparent delight teachers and students expressed about using technology.

The overwhelming emphasis was on reading outcomes, with comprehension as the most common of all outcome measures (65%); vocabulary, which we viewed as a member of the comprehension family, was a distant second, accounting for 10% of the outcomes. In terms of the emphasis of the interventions, the distribution was much more even than for outcomes. Most interventions attended to more than one aspect of reading; hence the highest incidence was for "mixed" emphases at 30% of the cases; for example, an environment would offer a hypertext learning environment with access to word pronunciation, word meaning, contextual information, and comprehension scaffolds to guide an individual's reading.

It seems plausible that those who work in this medium are attempting to take full advantage of its capabilities. Among the single emphasis programs, the focus was fairly evenly distributed among vocabulary (17%), word recognition (15%), independent reading (12%), and comprehension instruction (12%). The intervention codings were aggregated to create two categories: a meaning emphasis (mixed, comprehension, vocabulary, metacognition, and independent reading) and code emphasis (word recognition, phonemic awareness, and fluency). Of the 20 studies, 15 were categorized as meaning emphasis, with only 1 clearly as code emphasis and 3 categorized as other.

Analysis of Effect Sizes

The effect sizes (using the Hedges g correction for sample size) for all 89 outcomes are summarized (as averages weighted for the number of effect sizes in each study) in Table 2 for the 20 studies that survived all 3 screens.

As reported in Table 2, within a random effects model (Lipsey & Wilson, 2002), the weighted mean of these 89 corrected effect sizes is 0.49 ($sd = 0.74$) ($z = 4.36, p < 0.0005$).[4] All 89 effect sizes, along with the 95% confidence intervals, are portrayed graphically in Figure 1. The forest plot provides a simple visual representation of the amount of information and variation from the individual studies that are part of this meta-analysis (with the weighted mean effect size appearing as the right-most entry). In the plot, the weighted average (Hedges g) of all effect sizes for each study is shown as a vertical line with a diamond plus two tiny rectangles; the diamond is weighted effect size, and the two small rectangles indicate the limits of the 95% confidence interval for the effect sizes in any particular study.

On the basis of the overall mean weighted effect size, one can and should conclude that the range of digital technologies used to ameliorate the reading performance of middle-school students is quite effective; in terms of the norms for meta-analysis (Cohen, 1988), this would qualify as a "moderate" overall effect size (0.5–0.8). When examined as percentages, of the 89 effect sizes calculated, 26% were large (>0.8), 32% were moderate (0.5–0.8), and 42% were "small" or lower (0.01–0.5). The key term here is range, for there are many types of interventions; clearly, some are not any more effective than garden-variety print-oriented instruction while others produce sizable advantages over conventional approaches.

[4]Please see Pearson et al. (2005) for complete statistics on the individual effect sizes.

TABLE 2
Data on the Mean Weighted Effect Sizes for Each Study

	Number of Effects	Hedges's g	Standard error	Variance	95% Confidence Interval Lower limit	95% Confidence Interval Upper limit	Z-Value
Alfassi	3	0.815	0.352	0.124	0.125	1.506	2.314*
Dalton	1	0.424	0.204	0.042	0.023	0.825	2.075*
Gentry	3	0.135	0.279	0.078	−0.412	0.682	0.483
Fasting	6	0.584	0.284	0.080	0.028	1.140	2.059*
Hasselbring	4	0.521	0.181	0.033	0.166	0.875	2.876**
Henao	4	0.668	0.451	0.203	−0.215	1.552	1.483
Higgins	1	0.600	0.261	0.068	0.089	1.111	2.301*
Jones	10	0.334	0.193	0.037	−0.044	0.712	1.731
Kramarski	3	−0.204	0.283	0.080	−0.758	0.350	−0.721
Leu	6	0.503	0.303	0.092	−0.090	1.097	1.662
Ligas	8	0.029	0.093	0.009	−0.153	0.210	0.312
Liu	3	2.679	0.361	0.130	1.971	3.387	7.420**
Reinking88	12	0.214	0.251	0.063	−0.278	0.706	0.852
Reinking90	7	0.691	0.371	0.138	−0.036	1.419	1.863
Rouse	4	0.060	0.136	0.018	−0.206	0.326	0.442
Salomon	4	1.563	0.321	0.103	0.933	2.192	4.862**
Solan	1	0.664	0.365	0.134	−0.053	1.380	1.816
Underwood	1	−0.027	0.174	0.030	−0.367	0.314	−0.153
Vollands	6	0.374	0.388	0.150	−0.386	1.134	0.965
Xin	6	0.264	0.229	0.052	−0.184	0.712	1.155
Random Effects model	Total of 89 effect sizes	0.489	0.112	0.013	0.269	0.709	4.360**

$^{*}p < .05$, $^{**}p < .01$

Examining Simple Effects within Categories

Of particular interest for our purposes is a set of very specific comparisons related to the variations in programmatic, assessment, and contextual variables. For example, for the 57 effect sizes reported for a general, undifferentiated population of middle school students, the mean effect size was 0.52, whereas the effect size for targeted populations of students (e.g., students classified as possessing learning disabilities or as struggling readers) was 0.32 ($N_{es} = 29$); this was a statistically reliable difference, $Q = 4.42$, $p < 0.05$. In comparing meaning-focused interventions (the combination of mixed, comprehension, vocabulary, and metacognition) with those that were code-focused (the combination of phonics, phonemic awareness and fluency), we found no mean effect size difference favoring one emphasis over another, $Q = 1.82$, $p > 0.05$. The mean weighted effect size among studies emphasizing meaning was 0.43 ($N_{es} = 70$) compared to 0.20 for code ($N_{es} = 12$).

Study duration, we reasoned, was important, due to the common observation among intervention studies that pedagogical experiments often fail to show

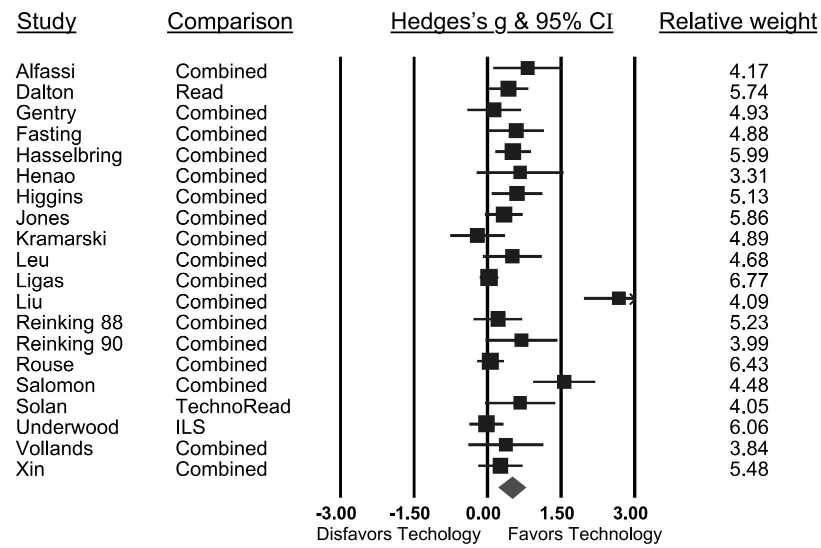

FIGURE 1 Forest Plot of the 89 effect sizes for the 20 studies (random effects model)

effects because the intervention does not have time to "take hold." Our results did not confirm the "longer is better" conventional wisdom; we instead found a "U-shaped" distribution of effects that, while provocative, was not statistically reliable, $Q = 2.23$, $p < 0.33$. Effect sizes in studies lasting two to four weeks ($N_{es} = 21$, $ES = 0.55$) were larger than those in studies lasting less than a week ($N_{es} = 25$, $ES = 0.48$) but much larger than those from studies lasting five or more weeks ($N_{es} = 43$, $ES = 0.34$).

Sample size was a robust predictor of effect size; small *n* studies (30 or less) produced 14 effect sizes averaging 0.77, while large *n* (31 or more) studies produced 75 effect sizes with a mean of 0.38, $Q = 3.24$, $p < 0.20$. The possibility exists that the loss of control that comes from larger scale implementation of interventions, especially when they are implemented for longer periods of time, may result in a loss of power and precision; this is certainly a plausible hypothesis for a larger meta-analysis encompassing many other subject areas and target populations.

Whether a study controlled for pretest equivalency through random assignment ($N_{es} = 44$, $ES = 0.42$) or some sort of pretest covariate ($N_{es} = 45$, $ES = 0.45$) did not account for a significant amount of variation in effect sizes, $Q = .16$, $p < .69$. On the other hand, the type of test used to measure outcomes revealed substantial and statistically significant differences in effect size, $Q = 18.62$, $p < 0.01$. Tests produced by test companies, largely standardized measures (N_{es} = 41, ES = 0.30), were less sensitive to treatment effects than experimenter-designed assessments (N_{es} = 34, ES = 0.56). Other (a catchall category) tests produced an effect size of 1.05, but there were so few effect sizes (N_{es} = 3) that little credence can be given to that estimate.

We also examined effect sizes by their "policy focus," categorizing studies according to whether their primary purpose was to (a) reduce the achievement gap, (b) increase technology use in general, or (c) improve a specific educational outcome, such as reading comprehension. We found no statistically significant differences ($Q = 1.68$, $p > 0.05$). For the 25 effect sizes coming from studies designed to improve the achievement gap, the mean effect size was 0.55, whereas the mean effect size for the studies (N_{es} = 30) designed to increase general technology use was 0.36. The mean effect size for the studies (N_{es} = 34) designed to improve a specific educational outcome was 0.41.

Another variable of interest is what we dubbed *technology source*, for lack of a more precise label. It contrasts whether the technology originates with a commercial source (e.g., programs such as Fast Forward or Accelerated Reader), the researcher's personal vision of what a technological learning environment ought to look like (e.g., Hasselbring & Goin, 2004), or a well-studied "delivery system," such as electronic text with a dictionary available for word pronunciation and meaning. When we grouped studies on that variable, the differences were quite compelling and statistically significant, $Q = 32.19$, $p < 0.0001$. The 34 effect sizes from the commercial studies yielded a mean weighted effect size of 0.28, while the 44 effect sizes from delivery system studies averaged 0.34, and the 11 effect sizes from researcher-designed interventions revealed an effect size of 1.20. There appears to be something special about those "tailored" systems designed by individual research teams for specific purposes.

While it was not central to our investigation, we were interested in whether publication venue was a reliable predictor of effect size. So we compared publication in technology journals (N_{es} = 25, ES = 0.54) with literacy journals (n = 30, ES = 0.36) with broader educational journals (N_{es} = 34, ES = 0.41). This difference was not statistically reliable, $Q = .1.73$, $p > 0.05$.

For convenience, these comparisons are summarized below in Table 3.

Summary of Results

This meta-analysis suggests a number of findings relevant to those interested in the use of technology to improve literacy acquisition and instruction at the middle-school level. As has been highlighted by others, little experimental research exists in this domain. The research that does exist focuses mainly on reading comprehension, with a little emphasis on metacognitive performances but virtually no attention to issues of motivation and engagement. This is all the more surprising given the common claims about the motivational value of

TABLE 3
Summary of Effects Between Levels of Relevant Variables—Random Effects Model

Moderator Variable: Levels	N_{es}	M_{es} *(Hedges g)*	*Lower Confidence Interval*	*Upper Confidence Interval*	*Q value*[a]
Student samples Size:					5.216*
30 or less	14	0.772	0.457	1.087	
31 or more	75	0.378	0.254	0.501	
Focus of intervention:					1.828
Code	12	0.200	−0.107	0.508	
Meaning	70	0.430	0.302	0.558	
Type of test:					18.62**
Test Co.	41	0.30	0.19	0.42	
Res Dev	34	0.56	0.21	0.92	
Other	3	1.05	0.72	1.38	
Country:					0.456
USA	64	0.408	0.274	0.541	
World	25	0.500	0.267	0.733	
Duration of Study:					2.412
<1 week	25	0.481	0.260	0.701	
2–4 weeks	21	0.545	0.321	0.770	
5 weeks +	43	0.342	0.185	0.500	
Pretest Equivalency:					0.056
Rdm Assnt	44	0.416	0.244	0.589	
Others	45	0.445	0.284	0.605	
Publication Type:					1.730
Tech	25	0.541	0.334	0.747	
Reading	30	0.358	0.162	0.554	
Other	34	0.400	0.221	0.580	
Focus of Policy:					1.68
↓ Ach Gap	25	0.55	0.34	0.75	
↑ Techn	30	0.36	0.17	0.56	
Oth Outc	34	0.41	0.22	0.59	
Target Population:					4.42*
GenEd	57	0.52	0.377	0.655	
Other	32	0.28	0.100	0.457	
Tech Source:					32.19**
Commercial	34	0.28	0.117	0.433	
Delivery	44	0.34	0.192	0.493	
ResDev	11	1.20	0.912	1.491	
Experimental Design:					4.432*
Independent Groups	59	0.35	0.211	0.482	
Correlated	30	0.60	0.406	0.802	

a: Q values with $p < 0.05$ indicate that effect sizes differ significantly across levels of the moderator variable. $*p < 0.05$; $**p < 0.01$

technology. This caveat notwithstanding, our analysis suggests that a wide range of digital technologies appears to enhance the reading performance of middle school students as evidenced by the robust overall effect size obtained in this meta-analysis. In addition, a number of specific outcomes merit our attention as a field:

1. The effect sizes were greater for interventions aimed at general populations than those with specific needs (i.e., students who are learning disabled or struggling readers). We can only speculate about why this might be the case, and we surely need more evidence before reaching a definitive conclusion. However, issues of engagement and appropriate levels of support and feedback suggest themselves as reasonable explanations.
2. Standardized measures from test companies were less sensitive to treatment effects than researcher-developed measures in several of the studies in this meta-analysis.
3. Studies with smaller sample sizes were much more likely to achieve substantial effects than those with larger sample sizes. This counter-intuitive finding is puzzling because of what we know about the increase in statistical power that comes with larger experimental samples. On the other hand, there may be a trade-off between statistical power and experimental precision; that is, it may be easier for researchers to maintain a high degree of fidelity to treatment in smaller studies because of the greater manageability prospects.
4. Technologies that were created by a research team had a much larger effect size than those technologies either adapted from the commercial market or those that merely used the technology as a delivery system. This finding may be related to the fact that those technologies created by researchers tended to have a clear theoretical focus that was matched by the assessments employed by the team. In short, alignment between intention and outcome measure may be the operative variable behind this robust finding.
5. Studies that used some sort of correlated design (pretests used as covariates for posttest or repeated measures designs in which the same subjects cycle through different interventions) are more likely to find reliable differences between interventions than are independent group designs.

SUGGESTIONS FOR POLICY AND PRACTICE

We undertook this meta-analysis to determine the state of research-based knowledge about the role of technology in improving reading performance in the middle-school grades. Of particular importance were the use of digital technologies to improve five areas of literacy acquisition: independent strategy use, metacognition, reading motivation, reading engagement, and reading comprehension. Unfortunately, we were able to locate studies addressing primarily reading comprehension and vocabulary, with three studies investigating phonological aspects of reading.

As we already suggested, this is a grave concern given the hope we collectively express for the motivation and engagement that technology ought to promote among learners, particularly learners who have not experienced success with conventional curricular tools. That said, the research we located is encouraging, for it shows that these digital learning environments and tools can impact learning. These findings have some implications for curricular practice and for research.

Recommendations for Practice

Suggesting a strong causal link between findings in any research synthesis and everyday practice in schools and classrooms is always fraught with danger and must be accompanied by pleas for caution in extrapolating findings across populations and contexts. Nonetheless, based on the robustness of particular findings, we feel that the following three recommendations can be followed with confidence.

1. *The overall positive impact of technology environments, especially on comprehension outcomes, should prompt us to feel comfortable in recommending broader implementation of programs that have undergone careful evaluations of their effects on student learning.* Even though we are tempted to say that educators should consider the adoption of programs that possess the same features as those shown to be effective in this analysis (e.g., focus on meaning, using a mixed set of technology tools), we think it safer for consumers to require careful evaluation of any specific technology program before recommending widespread adoption.

   Moreover, the relatively modest impact of commercial programs should prompt us to adopt a highly skeptical stance toward claims made by individual vendors and redouble our insistence on high quality, independent evaluations of commercial products prior to adoption. (In an earlier era, the Educational Products Information Exchange [EPIE] served as a kind of "Consumer Reports" for educational products. The EPIE can be found at: http://www.epie.org/html/aboutus.htm. With the proliferation of software packages and hardware tools, it is needed now more than ever. Perhaps the What Works Clearinghouse can serve such a function.)

2. *Program adoption for populations of struggling readers requires even more careful evaluation.* Our data analyses suggest that positive outcomes for struggling readers are much harder to come by. Given the focus of current policy on interventions for struggling readers, students with learning disabilities, and other special populations, we believe it would be unwise to adopt a program that had not shown an effect for a specific target population. We also believe, and explicitly suggest, that much greater emphasis on research on tools designed especially for struggling readers is needed.
3. *Current reading assessments, especially commercial assessments, do not appear sensitive to the interventions possible through technology.* Somehow commercial assessments do not capture what these interventions are all about, and we believe, as we suggest below in our recommendations for future research, that we need more assessment instruments that exhibit greater instructional sensitivity. The current crop of standardized tests is held to a high standard for criteria of reliability and concurrent validity, but there is little evidence of each test's instructional validity (i.e., sensitivity to changes in performance due to instruction). We need assessment instruments that provide more sensitive tests of the efficacy of instructional interventions in this burgeoning technology enterprise.

Recommendations for Future Research

As we consider future research in this area, a few recommendations deserve our collective consideration and action:

1. *The present data reinforce the many existing calls for more research in this area.* If one puts together three key findings from this meta-analysis [(a) there are not enough experimental studies, (b) there is a narrow focus on cognitive outcomes (comprehension), and (c) the existing studies show promising effects on literacy acquisition], one is led to the conclusion that we should continue, perhaps even expand, funding for research on technological interventions to improve literacy acquisition at the middle-school level. As promising as it is, there is just too little research to allow for us to make strong claims about the efficacy of technology on literacy. After multiple filtering phases to ensure the correct population, the appropriate intervention, and rigorous research, only 20 studies survived. As such, only one of the five initial research questions could be answered. Funding for future research should move beyond existence proofs (technology can make a difference) to provide more specific and nuanced information about when, where, why, and how technology can support teaching and learning for middle school literacy acquisition. Our call for research echoes the

concerns and needed directions expressed by leading authors in literacy and technology (e.g., Labbo & Reinking, 1999; Leu, 2006). This future research should examine *all* areas of reading, including those relatively unexamined by the studies we found (e.g., strategy use, metacognition, motivation, and engagement).

Future research may need to balance issues of focus against standards of control and precision. The largest effect sizes in this meta-analysis were from studies that used a smaller *n*; moreover, there is a tendency, albeit nonsignificant for shorter studies to produce greater effects. This suggests that research studies that last too long might be open to maturation effects or other confounding variables. Research that takes place too quickly might not provide time for the intervention to take hold. Studies with large sample sizes might compromise researcher control that would be available in a smaller, more manageable study. The larger issue implied by this recommendation is the question of what research methods ought to be employed in the conduct of research in this or any other educational arena. Complementarity, it seems to us, is called for in this arena. The complementarity principle would suggest that in any venture, we begin with small-scale descriptive studies before moving on to more careful design or formative experiments that help us narrow the range of relevant variables in anticipation of carefully controlled randomized experiments and, finally, studies of what happens in the scaling-up process. This principle seems even more important in a relatively new field, such as the development of digital tools to enhance literacy learning.

2. *As a field, we should develop a master codebook that could serve the research community as a heuristic for analyzing digital technologies and their impact on literacy acquisition in the middle-school grades (perhaps beyond).* This recommendation originated in the work of Cavanaugh et al. (2004), and its utility was once again demonstrated in this meta-analysis. There are many complexities related to studying digital tools and their impact on literacy acquisition; a research field without such a heuristic will find it difficult to compare outcomes or to come to any concrete conclusions about implications for teaching literacy at this level. We found the Waxman system (Pearson et al., 2005), with a few tweaks to make it more literacy-centric, to be quite useful to us, and we would recommend it to others. This codebook would be a collection of major categories, as well as variables within those categories. The codebook used in this study can be found in Appendix G.
3. *Future research needs to examine the relation between commercial products and researcher-developed technology interventions*. Little research has investigated commercial technology products used for improving literacy acquisition at the middle-school level. However, this meta-analysis has

provided evidence that researcher-developed technologies seem to be more effective than their commercial counterparts. This finding could be due to the fact that, in several of the studies in our corpus, the researchers also developed the measures used to determine the effectiveness of the program. As such, the measures may be "testing the tool" rather than striving for transfer.

It is also possible that, by working together, researchers, educators, and technologists are better able to create a system tailored specifically to meet the needs of particular audiences than commercial products trying to serve large audiences. As we will argue later, stronger, more valid, and more reliable measures (along with a better coding heuristic) will help address this issue of whether the difference between commercial programs is an artifact of the match between assessments and programs or a result of more careful implementation of a learning environment. If it is the case that researchers are better able to develop effective literacy tools, then better dissemination plans need to be enacted to share these benefits with practitioners—and possibly with the educational publishing community, so that they can infuse promising new technological innovations into their products.

Two other recommendations for research are only indirectly implied—certainly not licensed—by our meta-analysis, but both are worth mentioning because they are so central to the future of research in this area.

1. *Assessment*. Our meta-analysis did unearth assessment, especially the question of what sorts of assessments should count as evidence of the efficacy of a technological intervention, as an issue. We believe that the research on digital tools for middle school literacy acquisition should include a focus on developing measures to evaluate outcomes that are generalizable, comparable, and replicable. We found that researcher-developed measures yielded greater effect sizes than external standardized tests. Is it because these highly curricular-embedded, researcher-developed tests are more relevant to the treatment and hence more valid—or just a reflection of what happens when a program teaches to the test and, in the process, compromises the generalizability of the intervention compared to what might have been achieved with standardized measures? We are not sure, but we are sure that the issue needs our scholarly attention.
2. *Engaging teachers in technology interventions.* Few would argue with the assertion that teachers need practical information to learn how to best use digital tools in the classroom. As a research field, we are still a long way from helping teachers implement effective classroom technology systems. Thus, we would welcome research on how to assist

teachers in implementing technology. However, more is needed. Most of the interventions in our analysis put the researcher at the center of the classroom implementation of the technology and positioned the teacher as a bystander. We need collaborative research, beginning perhaps in the spirit of design research (Bannan-Ritland, 2003), that engages teachers from the outset in the design and implementation of classroom digital tools. Only when researchers engage teachers from the conceptualization of their technology tools can researchers benefit from the wisdom of teaching in their designs. Only when researchers expand their methodological repertoire to include iterative design experiments in advance of randomized field trials will there be a place for teachers to engage in full and continuous collaboration.

Finally, a comment for those who would raise the issue of whether it is worth doing a meta-analysis on a corpus of only 20 studies: There appears to be a general belief among some educational researchers that a large number of studies must be included in a meta-analysis project to draw substantive conclusions. For example, the National Reading Panel on Technology (2000) decided not do a meta-analysis because there were only 21 studies identified. Given the wider range of grades and questions asked in that initiative, perhaps the number of studies would not have been sufficient. However, even in that effort, we should note that, even though no meta-analysis was carried out, the NRP found that all 21 studies indicated the positive effects of technology on reading performance and reached positive conclusions about its efficacy.

By focusing on an undefined and statistically unsupported assumption about a minimum number of studies to carry out a meta-analysis, the more relevant concept of heterogeneity is obscured. Heterogeneity refers to the fact that studies grouped together in a systematic review will differ in a variety of systematic and random ways. The differences can be in experimental design, outcomes measures reported, and other factors. Statistically, heterogeneity means that observed treatment effects differ more from each other than one would expect from random factors alone. Thus the more important task to carry out in meta-analysis is to more precisely abstract useful and homogeneous information from the studies and manipulations of the specific construct(s) of interest.

Hardy and Thompson (1998) examined various factors that impact the power of a heterogeneity test. They included such factors as the number of studies, the total information available, and the distribution of weights. Their findings show that the power increases with the total amount of information, not merely the numbers of studies in a meta-analysis. Hardy and Thompson also showed that, if a particular study contributes an inordinately large amount to the overall weighted mean effect size, the power is substantially lowered.

Given two important facts—(a) that this meta-analysis had a very specific focus of reading and technology in Grades 6–8 and (b) that our admittedly small number of studies provided a large amount of information about the effects of technology on reading—we can be more confident about our findings and conclusions. Granted, our meta-analysis would be stronger if there were many more experiments available, but we believe we have made a solid beginning in looking at technology and reading, at least of our woefully understudied target population of middle school students.

We also note that no single study in our meta-analysis overwhelmed the other studies in terms of contributions to the overall weighted mean (this can be seen by examining the column of relative weight on the forest plot in Figure 1). Hardy and Thompson (1998) conclude their article by pointing out that that expert judgment deserves as much weight as statistical analyses of heterogeneity in determining weight and significance.

Our confidence in recommending more policy and research attention to technology, thankfully, is supported by the dual criteria of statistical scrutiny and wisdom. We believe the time has come to take technology more seriously as a component of middle-school literacy curriculum and pedagogy.

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APPENDIX A: Adapted WWC Study Review Rubric

Author:

Title:

Source:

Disposition: Acceptor Reject

RELEVANCE SCREENING CRITERIA		
Relevance of Intervention: Is the intervention relevant to the WWC review?	Yes	Any other pattern of responses
Relevance of Sample: Is the study's sample relevant to the WWC review?	Yes	
Recency of Study: Was the study conducted during a time frame appropriate to the WWC's review?	Yes	
Relevant Outcome Measure: Does the study contain at least one outcome measure relevant to the WWC's review?	Yes	
Valid Outcome Measure: Does the content of the outcome measure have face validity or adequate reliability[2]?	Yes	
Eligibility decision for this study	Study is eligible for WWC review	Study is not eligible for WWC review

CAUSAL VALIDITY STANDARDS		
Study Design: Does the study design appear to be a randomized controlled experiment (RCT), a quasi-experiment with matching (QED), or a regression discontinuity design (RD)]?[3]	Yes	No
What is the study design?	RCT, RD, QED	
Eligibility decision for this study	Study is eligible for WWC review	Study is not eligible for WWC review
Randomization: Were participants placed into groups randomly?[4]	Yes	Any other pattern of responses
Baseline Equivalence: Were the groups comparable at baseline, or was incomparability addressed by the study authors and reflected in the effect size estimate?	Yes or No[5]	
Differential Attrition: Is there a differential attrition problem that is not accounted for in the analysis?	No	
Overall Attrition: Is there a severe overall attrition problem that is not accounted for in the analysis?	No	
Disruption: Is there evidence of a changed expectancy/novelty/disruption, a local history event, or any other intervention contaminants?	No	
WWC Causal Inference	Meets Evidence Standards	Meets Evidence Standards with Reservations[6]
Comparability[7]: Were the groups comparable at baseline, or was incomparability addressed by the study authors and reflected in the effect size estimate?	Yes	Any other pattern of responses
Differential Attrition: Is there a differential attrition problem that is not accounted for in the analysis?	No	
Overall Attrition: Is there a severe overall attrition problem that is not accounted for in the analysis?	No	
Disruption: Is there evidence of a changed expectancy/novelty/disruption, a local history event, or any other intervention contaminants?	No	

CAUSAL VALIDITY STANDARDS (continued)		
WWC Causal Inference	Meets Evidence Standards	Meets Evidence Standards with Reservations[8]
Baseline Equivalence: Were the groups equivalent at baseline, or was incomparability addressed by the study authors and reflected in the effect size estimate?	Yes	Any other pattern of responses
Differential Attrition: Is there a differential attrition problem that is not accounted for in the analysis?	No	
Overall Attrition: Is there a severe overall attrition problem that is not accounted for in the analysis?	No	
Disruption: Is there evidence of a changed expectancy/novelty/disruption, a local history event, or any other intervention contaminants?	No or Yes	
WWC Causal Inference	Meets Evidence Standards with Reservations	Does Not Meet Evidence Standards
OTHER STUDY CHARACTERISTICS: INTERVENTION FIDELITY		
Documentation: Is the intervention described at a level of detail that would allow its replication by other implementers?	Yes	Any other pattern of responses
Fidelity: Is there evidence that the intervention was implemented in a manner similar to the way it was defined?	Yes	
Rating for Intervention Fidelity	Fully Meets Criteria (●●)	Meets Minimum Criteria (●)
OTHER STUDY CHARACTERISTICS: OUTCOME MEASURES		
Reliability: Is there evidence that the scores on the outcome measure were acceptably reliable?[9]	Yes	Any other pattern of responses
Alignment: Is there evidence that the outcome measure was overaligned to the intervention?[10]	No	
Rating for Outcome Measures	Fully Meets Criteria (●●)	Meets Minimum Criteria (●)

OTHER STUDY CHARACTERISTICS: PEOPLE, SETTINGS, AND TIMING		
Outcome Timing: Does the study measure the outcome at a time appropriate for capturing the intervention's effect?	Yes	Any other pattern of responses
Subgroup Variation: Does the study include important variations in subgroups?	Yes	
Setting Variation: Does the study include important variations in study settings?	Yes	
Outcome Variation: Does the study include important variations in study outcomes?	Yes	
Rating for People, Settings, and Timing	Fully Meets Criteria (●●)	Meets Minimum Criteria (●)
OTHER STUDY CHARACTERISTICS: TESTING WITHIN SUBGROUPS		
Analysis by Subgroup: Can effects be estimated for important subgroups of participants?	Yes	Any other pattern of responses
Analysis by Setting: Can effects be estimated for important variations in settings?	Yes	
Analysis by Outcome Measures: Can effects be estimated for important variations in outcomes?	Yes	
Analysis by Type of Implementation: Can effects be estimated for important variations in the intervention?	Yes	
Rating for Testing within Subgroups	Fully Meets Criteria (●●)	Meets Minimum Criteria (●)
OTHER STUDY CHARACTERISTICS: ANALYSIS		
Statistical Independence: Are the students statistically independent (i.e., the outcomes for some participants in a group are unrelated to the outcomes of others in that group) or, if there is dependence, can it be addressed in the analysis?	Yes	Any other pattern of responses

OTHER STUDY CHARACTERISTICS: ANALYSIS (continued)		
Statistical Assumptions: Are statistical assumptions necessary for analysis met?	Yes	
Precision of Estimate: Is the sample large enough for sufficiently precise estimates of effects?	Yes	
Rating for Statistical Analysis	Fully Meets Criteria (●●)	Meets Minimum Criteria (●)

APPENDIX B: Keywords Used for Web Searches

adolescent	middle grades
achievement	multimedia
cognitive	online
computer	open learning
computer-based instruction	quantitative
comprehension	quasi-experimental
digital media	phonemic awareness
educational technology	pretest, posttest
electronic media	print
evaluation	randomized
experiment	reading
hypermedia	research
hypertext	strategy
instruction	technology
Internet	textbook
intervention	validity
language	vocabulary
learning	web-based
learning environment	6th grade (or sixth grade)
meta-cognition	7th grade (or seventh grade)
middle school	8th grade (or eighth grade)

APPENDIX C: Academic and Educational Databases

Blackwell Science Synergy	ERIC
Directory of Open Access Journals	Gale Group Databases
Ebsco Research Databases	JSTOR

Ingenta Select
Kluwer
Lawrence Erlbaum Journals
MetaPress
OCLC FirstSearch–Periodical Abstracts
Ovid
ProQuest Education
PsychInfo
PubMed
Sage Publications
SpringerLink
Wiley Interscience
Wilson Education

APPENDIX D: Educational Technology and Reading Journals

American Educational Research Journal
American Journal of Distance Education
American Annals of the Deaf
Association for the Advancement of Computing in Education
Behavior Research Methods, Computers and Instrumentation
Children's Literature in Education
Communication Disorders Quarterly
Computer Science Education
Computers in Human Behavior
Computers in the School
Computers & Education
Contemporary Educational Psychology
Disability and Rehabilitation
Distance Education
Economics of Education Review
Education and Information Technologies
Education Policy Analysis Archives
Educational Psychology
Educational Psychologist
Educational Technology & Society
Educational Technology Research and Development
Electronic Journal for the Integration of Technology in Education
Elementary School Journal
E-learning
E-Learning and Education
Human and Computer Interaction
Human Factors
Information Technology, Learning and Performance
Interactive Learning Environments
Journal of Asynchronous Learning Networks
Journal of Adolescent and Adult Literacy
Journal of Applied Psychology

Journal of Computer Assisted Learning
Journal of Computer Mediated Communication
Journal of Computers in Math and Science Teaching
Journal of Computing in Childhood Education
Journal of Distance Education
Journal of Distance Learning
Journal of Education Technology Systems
Journal of Educational Computing Research
Journal of Educational Computing, Design & Telecommunications
Journal of Educational Media
Journal of Educational Psychology
Journal of Educational Research
Journal of Educational Technology Research and Development
Journal of Experimental Child Psychology
Journal of Experimental Psychology
Journal of Information Technology Education
Journal of Interactive Media in Education
Journal of Interactive Learning Research
Journal of Interactive Online Learning
Journal of Learning Disabilities
Journal of Literacy Research
Journal of Reading Behavior
Journal of Research in English
Journal of Research on Technology in Education
Journal of Teaching, Learning and Assessment
Journal of Technology Education
Journal of Technology Studies
Journal of the Learning Sciences
Language, Learning, and Technology
Language and Leading with Technology
Learning Disabilities: Research and Practice
Learning and Instruction
Learning and Leading with Technology
Journal of Special Education Technology
Open Education
Reading Online
Reading Psychology
Reading Research and Instruction
Reading Research Quarterly
Reading and Writing
Reading and Writing Quarterly
Research in Education
Scientific Studies of Reading

Technology and Learning
TechKnowLogia: International Journal of Technologies for the Advancement of Knowledge and Learning
The Reading Matrix

APPENDIX E: International Journals

Australian Educational Computing
Australian Journal of Education
Australian Journal of Educational and Developmental Psychology
Australian Journal of Educational Technology
Australian Journal of Language and Literacy
Australasian Journal of Educational Technology
British Educational Research Journal
British Journal of Educational Psychology
British Journal of Educational Technology
British Journal of Learning Disabilities
British Journal of Special Needs Education
Canadian Journal of Education
Canadian Journal of Educational Communication
Canadian Journal of Experimental Psychology
Canadian Journal of Learning and Technology
Enseñanza de las Ciencias
European Education
European Journal of Cognitive Psychology
European Journal of Education
European Journal of Psychology of Education
European Journal of Special Needs Education
Infancia y Aprendizaje
International Journal of Artificial Intelligence in Education
International Journal of Educational Technology
International Journal on E-learning
International Review of Research in Open and Distance Learning
Language & Literacy: A Canadian Educational e-journal
Oxford Review of Education
Revista de Ciencias Humanas
Revista Electronica de Investigacion Educativa
Revista Iberoamericana de Educacion
Turkish Online Journal of Distance Education
Scandinavian Journal of Educational Research
Scandinavian Journal of Psychology

APPENDIX F: Summaries of 20 Studies Accepted and Coded for Literacy/Technology Meta-analysis

Author & Year	*Title of Publication*	*Publication Outlet*	*Publication Summary*	*Findings & Results*
Alfassi, M. (2000).	Using information and communication technology (ICT) to foster literacy and facilitate discourse within the classroom.	*Educational Media International*, 37, 137–148.	The participants in this study were 23 8th grade students enrolled in a regular junior-high school. The setting was a social science classroom where the students were responsible for doing collaborative research utilizing computer technology while receiving and sharing their expertise with their peers.	Results support the hypothesis that learning communities may be an important strategy for enhancing the reasoning, problem solving and learning strategies of students utilizing computer technology.
Dalton, B., Pisha, B., Eagleton, M., Coyne, P., & Deysher, S. (2002).	Engaging the text: Reciprocal teaching and questioning strategies in a scaffolded learning environment.	Final report to the U.S. Department of Education. Peabody, MA: CAST	Using a modified random sampling approach the study field-tested reading comprehension software (*Thinking Reader)*, embedded with research-based instruction in 14 middle school classrooms Reading comprehension and on/off task behaviors were compared for a control group of 39 students offline with an experimental group of 64 students online.	The results indicate the experimental group achieved significantly higher comprehension gain scores and spent significantly more time on-task and responding during strategy instruction.

Author & Year	Title of Publication	Publication Outlet	Publication Summary	Findings & Results
Fasting, R. B., & Lyster, S. H. (2005).	The effects of computer technology in assisting the development of literacy in young struggling readers and spellers.	*European Journal of Special Needs Education*, 20, 21–40.	Fifty-two below-average readers and spellers, who used *MultiFunk*, a computer program designed to assist reading in grades 5–7, were randomly assigned as experimental and control groups ($N = 26 + 26$). Also, 114 students from the same population, were studied to monitor baseline changes in literacy development during the intervention.	Results indicate that computer-assisted reading has potential to aid and support the development of basic literacy skills for struggling readers and spellers.
Gentry, M. M., Chinn, K. M., & Moulton, R. D. (2004).	Effectiveness of multimedia reading materials when used with children who are deaf.	*American Annals of the Deaf*, 149, 394–403.	The purpose of the study was to assess the relative effectiveness of *Tprint*, sign, and pictures in the transfer of reading-related information to deaf children. CD-ROM-generated stories were presented, to 25 deaf students, in four different formats. A repeated-measure design was used to analyze participants' reading comprehension performance.	Significant differences were found among the four presentation options. One observation was participants switch from American Sign Language to Signed English when analyzing text. The study suggests that presenting stories on CD-ROM with multiple modes of reading cues, such as print, pictures, and sign language, may be an effective supplement to standard reading practices.

Author & Year	*Title of Publication*	*Publication Outlet*	*Publication Summary*	*Findings & Results*
Hasselbring, T. S., and Goin, L. I., (2004).	Literacy Instruction for Older Struggling Readers: What is the Role of Technology?	*Reading and Writing Quarterly,* 20, 123–144.	The study uses the *Peabody Literacy Lab* (PPL), a technology-based intervention program for older students who are struggling with literacy. The PLL was used with an experimental group of 63 students and a control group of 62 students from three different schools and in grades six through eight.	Results from the outcome measures (including the Stanford Diagnostic Reading Test) showed scores where generally higher for the experimental group on mean, standard deviations, and displayed evidence of pre-post testing gains.
Henao, O. (2002).	The ability of competent and poor readers to remember information from hypermedia and printed texts.	Infancia y Aprendizaje, 25, 315–328.	Compares the capacity of a group of students to remember main ideas and details of a text presented in hypermedia and in print. Half were considered competent readers and the other half poor readers, Subjects were 40 sixth grade children from a middle class private school, selected according to performance on a reading comprehension test administered to 70 total students in three different groups.	Analysis of results revealed that both competent and poor readers remembered more important ideas when they read a hypermedia text. As for remembering details, among the group of competent readers there were no significant treatment differences In contrast, among the group of poor readers, the users of hypermedia remembered more details than the users of print.

Author & Year	*Title of Publication*	*Publication Outlet*	*Publication Summary*	*Findings & Results*
Higgins, E. L., & Raskind, M. H. (2005).	The compensatory effectiveness of the Quicktionary Reading Pen II on the reading comprehension of students with learning disabilities.	*Journal of Special Education Technology*, 20, 31–43.	Thirty participants with reading disabilities aged 10-18 practiced using the pens for two weeks and were subsequently given a reading comprehension test over: (a) reading passages silently w. pen, and (b) reading passages silently w.o. pen.	Paired sample comparisons revealed significant differences under the two conditions in favor of using the pen ($p < .0001+$).
Jones, J. D., Staats, W. D., Bowling, N., Bickel, R. D., Cunningham, M. L., & Cadle, C. (2004).	An Evaluation of the Merit Reading Software Program in the Calhoun County (WV) Middle/High School.	*Journal of Research on Technology in Education*, 37, 177–195.	The authors did a quasi-experimental study of the reading software developed by *Merit Software* in several middle schools classrooms. The experimental group consisted of 119 students while the control group was 36. The purpose was to evaluate the effectiveness of *Merit* programs used for six hours by students in grades 6 and 8.	The results of the study showed the treatment group scored higher than that control group on several sub-tests of the Stanford Achievement Test (SAT-9). Students in the treatment group increased their Reading Vocabulary score by 13.1% of the total sample mean and their Reading Comprehension score by 10.5% when compared to the control group.

Author & Year	*Title of Publication*	*Publication Outlet*	*Publication Summary*	*Findings & Results*
Kramarski, B., & Feldman, Y. (2000).	Internet in the classroom: Effects on reading comprehension, motivation and meta-cognitive awareness.	*Educational Media International,* 37, 149–155.	Study examined an Internet reading environment, embedded with meta-cognitive instruction, intended to support students' comprehension, motivation and meta-cognition. The experiment included 52 students from 8th grade in two classes, randomly selected from one middle school. Students were assigned to two groups: (a) Internet group who was exposed to the internet reading environment; and (b) control group who was exposed to meta-cognitive instruction as part of in a regular instruction.	Results showed that the Internet environment had a significant impact on motivation but no significant impact on achievement on reading comprehension and meta-cognitive awareness.

Author & Year	*Title of Publication*	*Publication Outlet*	*Publication Summary*	*Findings & Results*
Leu, D., Castek, J, Hartman, D., Coiro, J., Henry, L., Kulikowich, J., & Lyver, S. (2005).	Evaluating the development of scientific knowledge and new forms of reading comprehension during online learning.	Final report submitted to the North Central Regional Educational Laboratory/Learning Point Associates. Retrieved January 7, 2008, from http://www.newliteracies.uconn.edu/ncrel_files/FinalNCREL Report.pdf	Examines whether science learning improves with online collaborative learning and Internet Reciprocal Teaching used to develop online reading-comprehension skills. The study population included 89 7^{th} grade students divided proportionately into three groups receiving graduated Internet instructional treatments and one control group with no Internet access.	Complete implementation of Internet teaching apparently supports increases in science concept learning and reading comprehension. However, incomplete integration of Internet teaching may impede learning science or other discipline-based concepts and result in reduce reading comprehension.
Ligas, M. R. (2002).	Evaluation of Broward County Alliance of Quality Schools Project.	*Journal of Education for Students Placed at Risk,* 7, 117–139.	This five-year project focused on reading performance, by at-risk middle school students. Strong emphasis was placed on Direct Instruction supported by CAI (*Accelerated Reader)*. A time series design compared students in grades 6–8 (2,300 students per grade level) who used CAI for 12 or more hours with students in the same schools who didn't use CAI or used it for less than five hours.	The experimental group outperformed the control group by 7.74 points on the SAT-8 Reading Comprehension test. Results suggest Direct Instruction linked with technology increases learning by effectively linking new knowledge to existing knowledge.

Author & Year	Title of Publication	Publication Outlet	Publication Summary	Findings & Results
Liu, M. (2004).	Examining the performance and attitudes of sixth graders during their use of a problem-based hypermedia learning environment.	*Computers in Human Behavior*, 20, 357–379.	Examines the impact of a problem-based hypermedia learning environment on sixth graders' performance and attitudes. Participants included 155 sixth graders from a middle school. A pre-post test, quasi-experimental design was employed to determine differential impact from a technology intervention (*Alien Rescue*) on participants' performance on problem-based tasks, writing, and on selected attitude measures.	Findings showed all participating students showed evidence of increased science knowledge, evidenced by significant gains between pre and post tests over science concepts. Participants we categorized into three ability groups: gifted, RegEd, and LD. Findings attributed the most prominent knowledge gains to RegEd & LD groups, but only minor differences in positive attitude change between the three groups.
Reinking, D. (1988).	Computer-mediated text and comprehension differences: The role of reading time, reader preference, and estimation of learning.	*Reading Research Quarterly*, 23, 484–498.	This study addressed whether middle grade students would understood text better when read on a computer display or in print. Subjects were 33, 5th and 6th grade students. All were classified as being either good or poor readers. Participants read expository passages in both print format and as text in three different computer presentations.	Results showed comprehension apparently improved when reading text on a computer. The reported increase was statistically significant when controlled for time.

Author & Year	*Title of Publication*	*Publication Outlet*	*Publication Summary*	*Findings & Results*
Reinking, D., & Rickman, S. S. (1990).	The effects of computer-mediated texts on the vocabulary learning and comprehension of intermediate-grade readers.	*Journal of Reading Behavior,* 22, 395–411.	Investigates whether the vocabulary learning and comprehension of a sample of 60 sixth-grade students is affected by displaying texts on a computer screen that provides the meaning of difficult words. The students were randomly assigned to one of 4 experimental conditions. The outcomes were measured using comprehension and vocabulary tests	It was determined that intermediate grade students reading science texts independently explored the meanings of more difficult words, recalled more of their meanings, and comprehended more content when they read passages displayed by a computer that provided immediate, context-specific assistance with vocabulary.
Rouse, C. E., & Krueger, A. B. (2004).	Putting computerized instruction to the test: A randomized evaluation of a “scientifically-based” reading program.	*Economics of Education Review*, 23, 323–338.	A randomized study testing the impact of a popular instructional computing program (*Fast For Word*) on language and reading skills. The study sample included approximately 244 experimental and 219 control group subjects in grades 3–6. Of these, 241 observations were for FFW Language exercises (elementary), 56 for FFW Middle School exercises and 150 for FFW Language to Reading exercises.	Findings suggest that although the FFW programs may improve some aspects of students’ language skills, it is not clear if these gains generalize generally to language acquisition or to actual improvements in reading skill. Results suggest that achievement gains schools can reasonably expect to achieve using the FFW programs are substantially more modest than those claimed by FFW’s vendor.

Author & Year	*Title of Publication*	*Publication Outlet*	*Publication Summary*	*Findings & Results*
Salomon, G., Globerson, T., & Guterman, E. (1989).	The computer as a zone of proximal development: Internalizing reading-related meta-cognitions from a reading partner.	*Journal of Educational Psychology*, 81, 620–627.	Based on Vygotskyt's theory of zone of proximal development, this study asked if computers used as tools supported meta-cognitive development. Participants included 25, 7th grade students. The *Reading Partner* software was used to present 11 texts in over 3 reading sessions. Two versions were employed in each session: "version 1" presented texts with factual and inferential questions, and "version 2 (control) presented only texts.	The experimental group showed statistically significant improvements in reading and writing scores. Researchers concluded that well-designed computer learning environment can enhance meta-cognititive competency.
Solan, H., Shelley-Tremblay, J., Ficarra, A., Silverman, M., & Larson, S. (2003).	Effect of attention therapy on reading comprehension.	*Journal of Learning Disabilities*, 22, 556–563.	Measured the influence of "visual attention therapy" on the reading performance of sixth grade students having moderate reading disabilities and absent other reading remediation. The study examined results for 30 total students; 15 experimental and 15 control group subjects.	After completion of computer-administered "attention therapy" over 12 weeks, mean standard attention and reading comprehension improved significantly for the experimental group while there was no apparent improvement in reading comprehension for control group subjects.

Author & Year	*Title of Publication*	*Publication Outlet*	*Publication Summary*	*Findings & Results*
Underwood, J. (2000).	A comparison of two types of computer support for reading development.	*Journal of Research in Reading*, 23(2), 136–148.	This study examines the impact of two different multi-media interventions on reading comprehension: (1) an integrated learning system or ILS (*Success Maker*) and (2) free reading, but using a "talking book" (*Living Books*). The ILS was employed with 108 experimental and 47 control group students in middle and high schools. "Talking books" were employed with 60 elementary school students.	In the experiment employing the ILS intervention, students in the experimental group demonstrated a strong preference for work on the ILS over the classroom. Based on an analysis of pre-post reading comprehension scores, no significant difference was found between the experimental and control groups.
Vollands, S. R., Topping, K. J., & Evans, R. M. (1999).	Computerized self-assessment of reading comprehension with the *Accelerated Reader*: Action research.	*Reading and Writing Quarterly,* 15, 197–211.	Quasi-experimental, action research exploring the formative effects of *Accelerated Reader (AR)* on reading achievement and motivation with students from two economically disadvantaged schools in the UK. In total, 39 P7 students participated (11 years old,	Pre-post scores were analyzed from two norm-referenced reading tests. Standardized scores (reading quotients) showed a significant increase on a test of silent reading comprehension for experimental subjects, but not for control. On a test of oral reading accuracy the

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			6th grade US), with 27 students initially assigned to the experimental group and 12 initially assigned to the control group.	experimental group showed a significant increase. On oral reading comprehension the experimental group showed no statistically significant increase but the comparison group showed a statistically significant *decrease*. Authors concluded using *AR* in this setting produced gains in reading achievement superior to regular classroom teaching or alternative intensive methods with less time devoted to in-class silent reading practice than in comparison classes.
Xin, J. F., & Reith, H. (2001).	Video-assisted vocabulary instruction for elementary school students with learning disabilities.	*Information Technology in Childhood Education Annual*, 87.	The study addresses whether video technologies can be used to improve basic reading skills, including vocabulary acquisition. In it, 76 students with learning disabilities, in 4th, 5th and 6th grade, were randomly assigned to a video instruction group and to a non-video control group for vocabulary and reading comprehension lessons.	Analysis of pre-post and follow-up achievement test scores indicated students in the experimental group (w. video instruction) showed statistically higher word acquisition scores than the control group.

APPENDIX G: Description of the Coding Characteristics

Major Category	*Brief Description of the Major Category*	*No. of Variables*	*Variables Examined In-depth*
Study characteristics	This category contained descriptive information about the study. It included the name, year, and author(s) of the article. It also included variables like gender, country, region, ethnicity, and target audience.	17	Author Year # of comparisons Student sample size Journal of publication Target population
Study of quality indicators	Variables within this category related to the factors helping determine the quality of the study. These variables included the name of the measure and its reliability, the pretest equivalency, and various outcomes	12	Duration of study Cognitive outcomes Affective outcomes Behavioral outcomes Effect size coefficient Weight
Sources of invalidity	History, maturation, selection bias, type of design, and selection-maturation interaction are all examples of sources of invalidity that were coded in this category.	14	The sources of invalidity in the codebook provided a way to examine whether the methodologies provided in the studies were rigorous enough to include the results in the meta-analysis. As such, all 14 variables were examined to help filter the selected corpus of articles.
Reading characteristics	The reading characteristics category included variables to describe both the focus of the intervention (what they did) and the outcome of the intervention (what they observed).	2	Examples of potential codes for the two variables included: Phonics Phonemic awareness Vocabulary Reading comprehension

Major Category	Brief Description of the Major Category	No. of Variables	Variables Examined In-depth
			Reading volume Reader response Fluency Independent reading Meta-cognition Content learning Spelling Word recognition
Technology characteristics	The technology characteristics category examined the technology features of the study. Variables included the type of technology used, the role or focus of the technology, and the teacher and students' prior experience with technology.	19	Aegis of technology
Instructional/Teaching characteristics	Instructional and teaching characteristics were examined in this category. Examples include the setting and mode of instruction, collaboration, and what types of conversations where encouraged in the pedagogy.	7	Unfortunately, in many cases, this information was not clearly delineated in the research article. Therefore, no information was gathered from the 19 articles to run meaningful analyses for this category.
Policy	The final category related to the policy focus of the study. This category contained two variables: the level of policy (i.e. state or national) and the policy focus.	2	Not enough information was included in most articles to analyze the level of policy. The policy focus was examined and included the following possibilities: Unspecified Reducing achievement gaps Increased use of technology Increased specific type of use Improve Specific Educational Outcomes

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