# *Reading and Studying on the Screen* and *Addendum*: two articles by Dr Mark Nichols


## Reading and Studying on the Screen: An Overview of Literature Towards Good Learning Design Practice

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## Abstract

As distance education moves increasingly towards online provision, and because of the benefits provided by online approaches, students will be expected to engage with more resources available on screen. Contemporary forms of reading from the screen include reading from tablet devices, LCD monitors, and smartphones. However, print remains the preferred means of reading text, and student preference for print is accentuated when reading involves thorough study (Ackerman & Lauterman, 2012; Foasberg, 2014). Education providers face an interesting challenge. Although many learners prefer having access to printed materials, on-screen reading can improve education's convenience, portability, media-richness, engagement, support, and data-evidenced practice. In this context it is timely to consider the potential for on-screen reading from the perspective of learning design. This article considers studies related to reading on screen, and suggests good practice principles for on-screen-only learning design.

**Keywords:** cognitive load; learning design; online-only; on screen; print

## Introduction

The screen is an everyday part of life for most people. Cell phones have evolved into smartphones, and telephony now serves only a minor role. Tablet devices are ubiquitous. Tablet sales are tipped to surpass traditional laptop and desktop sales in 2016, and mobile (and smartphone) sales will go well beyond both (Gartner, 2015). Banking, travel, retail, and multiple service sectors are all transformed as a result of online technology, and are further shaped by mobile devices and access. Information access is rapidly shifting on screen.[1]

Over time, reading from the screen has become the norm for a number of activities. The vast majority of people, for example, read and respond to emails without first printing them. Most adults in the United Kingdom now access newspapers and magazines online (Sweney, 2013), probably as a result of the uptake of tablet devices and smartphones. Books and academic journals are also increasingly electronic. In 2014, e-books comprised some 30% of all book sales in the United States (Bercovici, 2014); From January until August 2012, Amazon.co.uk sold 114 Kindle books for every 100 printed books (Malik, 2012). While evidence suggests the overall proportion of e-book to printed book purchasing may be stabilising at about 1:3 (Wallop, 2015), increasing investment in e-books and electronic journal services by higher education institutions means access to academic titles and articles is increasingly online. According to a Jisc survey, online journals have now largely replaced print versions for faculty research purposes

[1] The term 'on screen' is used here deliberately instead of 'online'. Online implies the need for consistent internet access. 'On screen' assumes that material might also be available offline – either by downloading or preloading the resources.

(Housewright, Schonfeld, & Wulfson, 2013[2]). Ready access to academic e-books is also improving, although title availability is not sufficiently ubiquitous and licencing arrangements are too challenging to make academic e-books a comprehensive solution for academic libraries at present (Walters, 2013).

## On-screen opportunities

The emphasis on the electronic word, the rapid uptake of tablets and smartphones, and the availability of internet connectivity provide substantial opportunities for providers of distance education. On-screen reading is no longer as inconvenient as it once was, and reading applications continue to develop. Over the last decade or so, resource-based providers of distance education provided printed materials to students in the form of printed learning guides and readings, complemented with online discussion forums, media (frequently on videotape, CDROM, or DVD), and external internet links. Additional learning materials can also be available online, although usually in a printable format. As the on-screen world becomes more familiar and central to academic research, an on-screen-only approach to education can be considered a step forward rather than a retrograde one—particularly if an on-screen approach involves more than simply converting a traditional print resource into an electronic format.

An enhanced on-screen-only provision of education provides multiple additional benefits:

- Effective on-screen reading skills are important for 21st century professionals.
- On-screen text can be seamlessly complemented with additional resources and references such as feedback activities, illustrative media, and glossaries.
- On-screen information is extremely portable (limited only by the device used to access it), and can be made available and synchronised across various devices.
- Development of on-screen text is streamlined and more efficient, as print materials tend to be produced electronically and then require additional formatting, pagination, publication, storage, and distribution. On-screen information can be readily, immediately, and cheaply distributed and amended.
- On-screen text can be manipulated and annotated by the end-user, and user notes can be easily shared. The user can manipulate text size and (frequently) font, colour, and contrast.
- Searches can be made for keywords across the whole text.
- Electronic accessibility services such as Read&Write for Google Chrome, and close captioning services, can be used by the reader (depending on the format).
- User activity can be passively tracked through analytics.

It is clear from this list that making print material available on screen (in the form of, say, PDF or ePub files) is neither the point nor the objective. While on-screen text certainly is cheaper to distribute, the potential advantages to tertiary education institutions and their students go well beyond this. A deliberate and leveraged on-screen approach to learning design results in a learning experience that goes well beyond the limitations of a print-based paradigm.

From the perspective of online distance educators, one of the more important aspects of on-screen reading is that of learning analytics, defined as "the measurement, collection, analysis, and reporting of data about learners and their contexts, for purposes of understanding and optimizing learning and the environments in which it occurs" (SoLAR 2011, in Ferguson, Macfayden, Clow, Tynan, Alexander, & Dawson, 2014, p. 121). Such data, already captured in virtual learning environment (VLE) transactions, becomes more powerful and discerning as more

[2] I used to print articles but read them on screen. However, paper provided me with security rather than focus, and this year I have stopped printing articles—although I do rotate my external monitor for a portrait view.

detail is provided. But although analytics data captured from individuals might provide insight into tutorial interventions—even where on-screen reading is not required—little can be gleaned about the design of the course. At the level of the individual student, analytics are completely meaningless if students print their course materials or read them outside the VLE. With on-screen reading analytics, "new ways of understanding trends and behaviours in students . . . can be used to improve learning design, strengthen student retention, provide early warning signals concerning individual students and help to personalise the learner's experience" (de Freitas et al., 2015, p. 1175). Improvements in the availability of analytics data will have a profound influence on the student experience for online and distance learning. Unprecedented insight into student behaviour in on-screen courses—at the collective level—will assist learning designers to craft materials based on actual use, resulting in more discerning, evidence-based and learning-friendly course materials. For example, analytics of the average time spent on a particular page, and the number of times students return to that page, can provide important clues as to the clarity of the material provided. The average study time and the influence of feedback exercises on average study time, can both be measured. As should be clear, the exercise does not aim to just garner better ways of presenting printed material on screen; instead, the intention is to optimise a text, media, and activity mix based on actual and objective feedback from collective use. On-screen materials, therefore, provide not only better access to richer materials but also their own feedback loop and evidence base. The passive collection of analytics data through on-screen engagement with materials alone provides significant potential to improve learning, and on-screen reading gives an immediate and detailed view of student progress and behaviour.

A print orientation to learning design results in a catch-22. If learning designers develop for a printable world, they are unable to model design approaches that demonstrate print independence. It is a courageous institution that seeks to adopt an on-screen approach to education, particularly because students have a negative perception of the institution merely passing on the costs of printing, and the well-documented evidence of student preference for printed materials (Ackerman & Goldsmith, 2011; Ackerman & Lauterman, 2012; Baron, 2015; Foasberg, 2014; Lauterman & Ackerman, 2014; Liu, 2005; Noyes & Garland, 2005; Vandenhoek, 2013; Woody, Daniel, & Baker, 2010).[3] Ultimately, however, the question of on-screen versus print transcends that of student preference. Learning designers must seek to provide an on-screen learning experience that goes well beyond what is printable. (This is not to suggest that nothing ought to be printed, as outlined later.)

Student success and learning should be central to the debate of on screen versus print. If an on-screen learning experience is designed so that it *improves* educational outcomes and support, debate of on-screen versus print takes on a different tone and purpose. The potential benefits of on-screen learning to students, and whether on-screen learning results in cognitive impairment, are central to this revised debate. The benefits have already been disclosed. To further advance the debate, this article now overviews the literature relating to cognitive impairment from on-screen reading, and explores the conditions for how on-screen learning approaches might better support students. The article concludes with some recommendations for developing effective on-screen learning resources.

[3] This perspective aligns with student feedback from both Open Polytechnic and The Open University. As I prepared this paper, there were no published studies identifying the percentage of students who prefer an on-screen-only education experience, but independent research conducted by Open Polytechnic indicates that it could be up to 20% of its adult distance learners.

## Comparing on screen with print

Outcomes from literature comparing the comprehension of readers reading print and on screen are mixed, although a meta-theme of no significant difference (NSD) can be broadly applied. This conclusion is straightforward enough, but it glosses over some important details. Dillon's (1992) sentiment that the differences between reading from screen and paper defy single variable explanation remains valid, although some key themes can be discerned.

The NSD finding has a consistency about it. In the late 1980s, in an early study comparing reading from CRT monitors with reading print, "no significant difference was found in either reading speed or comprehension between screen and paper, or between dark and light character displays" (Oborne & Holton, 1988, p. 1). According to Dillon (1992), early studies were unanimous that comprehension is not affected by on-screen or paper reading.[4] In addition to measuring reader comprehension, early studies were concerned with the influence of hypertext (that is, text that links to other sections), which tended to have a negative effect on student comprehension (Dillon, 1992). A meta-study, prepared some 15 years after Dillon's work, concluded that:

> . . . total equivalence [for reading from paper vs screen] is not possible to achieve, although developments in computer technology, more sophisticated comparative measures and more positive user attitudes have resulted in a continuing move towards this goal (Noyes & Garland, 2008, p. 1352).

Noyes and Garland's review considers the findings from multiple studies concerned with reading speed, accuracy, and comprehension. The authors conclude that "the situation is changing and it is probably fair to conclude that greater equivalence is being achieved today than at the time of Dillon's (1992) literature review" (Noyes & Garland, 2008, p. 1371). The variability of studies noted by Dillon, and Noyes and Garland, is more recently confirmed by Jabr in a sweeping summary of literature:

> [In studies] published since the early 1990s . . . a slight majority has confirmed earlier conclusions, but almost as many have found few significant differences in reading speed or comprehension between paper and screens (Jabr, 2013, para. 6).

Echoing Noyes and Garland, Jabr concludes that "[p]erhaps, then, any discrepancies in reading comprehension between paper and screens will shrink as people's attitudes continue to change" (ibid., para. 28). Even Baron, nostalgic to the point of heavy bias for print reading, concedes that "[n]early all recent investigations are reporting essentially no differences" (2015, p. 12). Indeed, several recent studies considering e-readers alongside paper and computer screens are emphatic that there is no difference in comprehension, whether you read on screen or from a printed page (Margolin, Driscoll, Toland, & Kegler, 2013; Subrahmanyam et al., 2013). A further study suggests that familiarity with tablet devices makes a positive difference to deep-level comprehension, and concludes that tablets are superior to computer displays (Chen, Cheng, Chang, Zheng, & Huang, 2014). Another study reveals evidence of no cognitive performance difference between using printed textbooks and electronic ones when overall grades and perceived learning are considered (Rockinson-Szapkiw, Courduff, Carter, & Bennett, 2013). Growing familiarity with reading from tablets and smartphones seems to be making a difference.

Importantly, computer vision syndrome (CVS) does not seem to be a factor against on-screen reading, as reading from the screen is no more physically demanding than reading from paper.

[4] It is useful to note here that Ackerman & Goldsmith (2011) also found no difference across subjects reading from CRT and LCD displays.

According to one meta-analysis, CVS is more likely to be caused by the position of the screen than by reading from it (Koslowe, Waissman, & Biner-Kaplan, 2011).

## NSD findings

A number of studies are unambiguous in their NSD findings (Margolin et al., 2013; Rockinson-Szapkiw et al., 2013; Subrahmanyam et al., 2013). Margolin et al. (2013) found no significant difference—for either recall or comprehension—between paper, computers, and e-readers. The study by Subrahmanyam et al. (2013) indicates that requiring critical engagement with material can improve comprehension. The study investigated simple, medium, and complex tasks that included recall, comprehension, and report writing for samples using print and on-screen sources; it also considered reading speed and comprehension for print, computers, and tablets while testing for the influence of user multi-tasking. While it took multi-tasking readers longer to engage with the passages, "there was no effect of medium on reading comprehension" (p. 11). The study found that even students reading from paper tend to be distracted by technologies, with texting and talking on cellphones being most common. In the second part of their study, Subrahmanyan et al. tested the rubric scores of one-page essays created by students who were provided with articles in print or by computer; or a computer, printer and internet combination. In the words of the study, "no significant differences were found between any of the three conditions for efficiency and output quality as measured by the [marking and grading] rubric" (p. 18), despite most respondents indicating they would prefer to engage with print. Subrahmanyam et al. also found no significant difference between paper, laptop, and tablet in reading or report-writing tasks. Finally, Rockinson-Szapkiw et al. (2013) found that e-textbooks are equivalent to print textbooks in terms of perceived learning and grades.

It is anticipated that technology will continue to improve the nature of the on-screen reading experience (Rockinson-Szapkiw et al., 2013). Indeed, in the Rockinson-Zsapkiw study, 90% of the 19.7% of students ($n$=106) who self-selected to use an e-textbook accessed it from a mobile device. It is also likely that the tools that are increasingly available to the on-screen reader (including note-taking, highlighting, social notes, enhanced displays, glossaries, and online links for further information) will continue to improve the effectiveness of on-screen reading (Subrahmanyam et al., 2013). While previous studies may have been concerned with comparing texts that are in a page fidelity format (that is, a printed page compared with a PDF version of that same page), the adaptive and enriched potential for reflowable texts (text that reapportions itself based on screen and font size) will probably result in on-screen options becoming more popular and effective. Further, there is evidence that students are becoming more familiar with digital annotation tools – to the extent that on-screen readers are more likely to type notes at source than to hand-write notes on printed materials (Rockinson-Szapkiw et al., 2013).

## Contrary studies considered

The literature associated with on-screen and print reading is beset by different study design in terms of both demographics and methodology. Although the conclusion of NSD is a defensible one when literature is synthesised, some recent studies comparing computer screens and print clearly find in favour of print (Mangen, Walgermo, & Brønnick, 2013; Wästlund, Reinikka, Norlander, & Archer, 2005) or else provide more nuanced results (Ackerman & Goldsmith, 2011; Ackerman & Lauterman, 2012; Chen et al., 2014; Lauterman & Ackerman, 2014). Two prominent reasons for these differences are overconfidence and cognitive load.

Several studies (Ackerman & Goldsmith, 2011; Ackerman & Lauterman, 2012; Lauterman & Ackerman, 2014; Liu, 2005) have identified overconfidence (when a person's subjective confidence is higher than it should be for effectiveness) as a feature of how on-screen readers tend to approach their reading tasks.

This overconfidence can be partly attributed to the reader's familiarity with processing brief on-screen readings such as email (which varies in its formality) or news items. Genre of use (that is, an internal sense that reading from the screen is a more casual and rapid exercise than reading from print) may be an important factor in overconfidence (Ackerman & Goldsmith, 2011; Ackerman & Lauterman, 2012; Liu, 2005). The Ackerman and Goldsmith (2011) study found NSD in cognitive performance for on-screen and print reading when performance was subject to a limited time. However, when the two groups were permitted to self-regulate time, the on-screen group were overconfident and did not perform as well. On-screen readers invested less time, and their performance in tests was lower than that of print students although most had made notes by marking up the document as they read. However, the subsequent study of Ackerman and Lauterman (2012), using the same methodology, reversed these findings; when given free time *with suggested time guidance*, on-screen participant scores were no different from those of paper participants. Under time pressure, though, the on-screen group did not perform as well. Again, overconfidence was a factor in the relatively poor performance of the on-screen group, and there was evidence that reader preference for reading print or on screen also played a part.

Such findings indicate that there is nothing inherently disadvantageous in on-screen reading except that readers tend to approach it differently. As the Ackerman and Goldsmith (2011) study notes, "although people are reluctant to study on screen, they can potentially do so as efficiently as on paper" (p. 27). On-screen readers are possibly not aware of the reading strategies that would assist their learning, or are not sufficiently experienced with on-screen reading for it to work for them. Lauterman & Ackerman (2014) found that "the consistent screen inferiority found in performance and overconfidence can be overcome by simple methods, such as practice and guidance on in-depth processing, even to the extent that some learners become able to perform as well on screen as on paper" (p. 462). Students for whom on-screen reading might impair cognitive performance *can* learn to read effectively on screen.

Cognitive load, the extent to which a reader's limited short-term processing memory is engaged with a task, is the second prominent reason for differences in study findings on on-screen and print reading. It is claimed that the cognitive load demanded by on-screen reading is greater than that for print, either from a lack of physical clues regarding progress, haptic familiarity (not having the same ability to engage with the page by touch), or the need for readers to engage with additional navigational activity such as scrolling (DeStefano & LeFevre, 2007; Lauterman & Ackerman, 2014; Mangen, 2008; Mangen et al., 2013; Margolin et al., 2013; Wästlund, Norlander, & Archer, 2008; Wästlund et al., 2005). Paper-based text has a definite fixity compared with on-screen text, and the physicality of a book or printed work provides additional navigational clues as to how far the reader has progressed. In contrast, e-reading forces a more virtual sense of navigation. It is theorised that this difference in navigability requires an e-text reader to focus on both progress and comprehension at the same time (Jabr, 2013; Mangen et al., 2013). However, cognitive load can decrease as tasks become more familiar and as strategies are made available, and learning strategies that improve cognition can also be suggested (Kalyuga, 2009); worked examples and effective diagrams are two additional means whereby the cognitive load of learning may be reduced (Ayres & Gog, 2009). Optimising page layout can also reduce the mental workload required for reading on screen (Wästlund et al., 2008). Cognitive loading is not an inevitable outcome of on-screen design strategies.

Reader distraction, primarily as the result of increased cognitive load, is also often cited as a disadvantage of on-screen reading (Baron, 2015). Studies confirm distraction has a detrimental effect on comprehension, whether it is from the temptations of social media (receiving an IM, or opening a browser to see the latest news) or heavily hyperlinked text (tempting a reader to click elsewhere on a related theme, and breaking their reading flow). It is particularly clear that use of hypertext increases cognitive load, and hypertext should be minimised if applied at all (DeStefano & LeFevre, 2007). Education designers must take care to ensure that on-screen

reading takes place with as little distraction as possible. Innovations such as Reading View in the Microsoft Edge browser are specifically designed to reduce the cognitive load of reading web pages.

Literature suggests that, where comparative findings for on-screen and print reading find in favour of print, overconfident on-screen reading and cognitive loading are culpable. Both of these factors can be addressed through deliberate learning design.

## Making on-screen learning work

The literature is clear that there are differences to the actual experience of on-screen reading, even if (ultimately) an NSD applies. Generally, literature confirms that:

- Extended text of more than 1200 words can be more difficult to engage with on screen.
- On-screen reading is typically perceived by readers of a genre to be not conducive to serious study.
- There are navigational and tactile differences between books and on-screen readers; on-screen text lacks the familiar physical markers readers use to assist with navigation and progress (resulting in haptic dissonance and increasing cognitive load).
- On-screen reading may require more mental effort (cognitive load), depending on how it is designed.

These differences indicate the means by which learning designers can improve the on-screen reading experience. In the words of Ackerman & Lauterman (2012), "computerized learning suffers not necessarily because the medium provides a less supportive technological environment, but because learners do not recruit enough cognitive resources to succeed in the task (e.g. attention, memorizing strategies, self-examination)" (p. 1817). Nor do comparative studies consider how the same learning outcomes might be addressed by print and a leveraged on-screen experience that includes analytics-based support, embedded media, social engagement, and feedback opportunities. Ultimately the solution lies in how learning designers leverage the on-screen experience to transcend what is possible in print.

If on-screen materials are to truly transcend print, a suite of learning design practices ought to be adopted. Having text on screen is not the goal. The literature indicates the following general learning design practices for effective on-screen learning, and to minimise cognitive load and improve student outcomes.

- Orientate students to the potential dynamics of on-screen reading, making them more deliberate and focused about their reading behaviour by:
    - contrasting reading as finding information, and reading as contemplating for understanding
    - encouraging electronic highlighting and note-taking to paraphrase and query the text
    - promoting focused reading, with all online distractions (such as Twitter feeds, browser tabs, Skype channels and IM clients) closed during the reading session
    - encouraging readers to monitor their progress against learning objectives, and to be deliberate about their understanding.
- If extended text is unavoidable, prompt the students as to how they should engage with it in the form of lead indicators (e.g., "Be sure you fully understand the context surrounding the diagram on p.13", "Pay specific attention to the method used in the study", or "Be sure you understand the main reasons behind the argument. It will be helpful for you to list them").
- Scaffold the cognitive load that is appropriate for the level of the student. Recognise that students taking early courses will probably need more guidance and feedback.

- Use a clean, reading-friendly on-screen interface without clutter and distraction.
- Minimise scrolling as a reader behaviour, so that text can be read in a more stationary way.
- Be deliberate in the design of on-screen text by:
    - chunking text logically, in similar sizes as much as possible
    - preparing on-screen text to optimise the on-screen display in a reflowable manner, to maximise flexibility
    - providing as much textual land-marking as possible, including diagrams, summaries, and position indicators
    - embedding activities and additional media in the text as part of a consistent presentation
    - as a guide, providing activities every 1000 words, to provide feedback and help reinforce key ideas and concepts (excepting book chapters or articles, which frequently cannot be edited)
    - minimising in-text hyperlinks and ensuring that any used are of direct relevance.
- If PDF formats cannot be avoided or extended text cannot be edited (for example in book chapters or articles), make these resources available through a print on-demand service, or provide versions that are easy to print.

Importantly, there should be a print option for extended narratives such as book chapters and scholarly articles. Given that such narratives are not easily broken up for activities, nor provide effective analytics data beyond when a student may have started or finished them, and because such files are often not screen-size friendly, there appears no good reason for print to be withheld. The challenge for learning designers is to ensure that such readings are essential, and not better summarised or alternatively presented. Whether such readings should be provided on enrolment or on demand, and who should pay for the printing, become interesting operational questions for institutions to answer.

## Conclusion

The debate as to whether distance education materials should be provided in print or on screen is demonstrated to go well beyond arguments of preference, and into the area of learning design. The literature largely confirms that there is no significant difference to learner comprehension if they read from print or on screen. Those studies that do find a significant difference cite overconfidence and additional cognitive load as being responsible for the lower efficacy of on-screen reading, and both of these factors can be addressed through a deliberate approach to educational design. Ultimately, the questions of on screen versus print come down to how an on-screen experience can be provided to maximise student success and equip students for the future.

Student orientation and designing for reduced cognitive load are foundational to their successful on-screen learning experience. Learning designers must build on these foundations to further enhance student success in the form of analytics-based support interventions, evidence-based learning design, and improved learning activities. Institutionally, the added reach and convenience of on-screen education enables further strategic possibilities while, at the same time, demanding more of its online systems.

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# Addendum: Reading and Studying on the Screen

**Mark Nichols,** The Open University

## Abstract

In 2016 the article "Reading and Studying on the Screen: An Overview of Literature Towards Good Learning Design Practice" (http://www.jofdl.nz/index.php/JOFDL/article/view/263/200) was published in the *Journal of Open, Flexible and Distance Learning* (Nichols, 2016b). The article overviewed comparative studies related to reading on screen and reading from print, and proposed recommendations for on-screen learning design. This addendum to that article considers additional studies that have been analysed in subsequent blog posts (see "An Update to 'Reading and Studying From the Screen'" [http://tel-lingit.blogspot.com/2018/02/an-update-to-reading-and-studying-from.html] and "A Further Update to 'Reading and Studying From the Screen'" [https://tel-lingit.blogspot.com/2018/11/a-further-update-to-reading-and.html]) up to the end of November 2018. As this is an invited addendum, I'll take the opportunity to adopt a more personal and self-disclosing style to talk more about my own position and experience regarding digital education and on-screen reading. This piece alternates is both scholarly and polemic.

**Keywords:** cognitive load; learning design; online only; on screen; print

## Introduction

The issue of whether digital education should require students to read from a screen has been one I have encountered frequently over the last 15 years. In 2015 I was working for Open Polytechnic as the first of many courses were released in a solely online, on-screen mode (see Nichols, 2016b, for a description of what this immediately led to). I am a strong advocate of digital education: I'm also well aware of the reluctance many academics and students feel about on-screen reading. In 2015 (perhaps belatedly) I decided to review the literature related to on-screen reading and comprehension, as these are important to digital study. I was both surprised and bemused to learn that such studies tend towards concluding there is no significant difference (NSD) between reading on screen and in print. In the detail of these studies I discovered factors that can make "on screen" a more effective medium. My 2016 article provided advice to learning designers that would mitigate the uncritical reading style on-screen readers can tend to adopt in an attempt to make on-screen study more effective and engaging.

Because the issue of screen versus print remains contentious, and also prompted by discussions at the Open University UK, I decided to keep an eye on the literature to see whether my advice remained relevant and my summary of the literature further substantiated. At the end of November 2018, the additional articles I've since considered (some published subsequent to my article and others not initially included) tend to confirm my initial work, and further nuance it. This addendum reports on what 29 of those articles have added to the work first published in

2016. The additional articles were recommended by Mendeley[1] as a complement to my previous study in the area.

It's fair to summarise the literature findings as represented in my 2016 article as follows.

- The experience of reading on screen is different from reading print; however, there is NSD overall in terms of comprehension.
- Extended text (more than 1200 words) can be more difficult to engage with on screen, and it may be that significant differences—in favour of print—occur beyond this word count.
- On-screen reading is typically perceived by readers to be of a genre not conducive to serious study.
- There are navigational and tactile differences between books and on-screen readers. On-screen text lacks the familiar physical markers that readers use to assist with navigation and progress (resulting in haptic dissonance and increasing cognitive load).
- On-screen reading may require more mental effort (cognitive load), depending on how it is designed.

I concluded that learning designers could apply techniques that would improve the performance of on-screen readers.

**Recommendations**

- Orientate students to the potential dynamics of on-screen reading, making them more deliberate and focused about their reading behaviour by:
    - contrasting reading as finding information, and reading as contemplating for understanding
    - encouraging electronic highlighting and note-taking to paraphrase and query the text
    - promoting focused reading, with all online distractions (such as Twitter feeds, browser tabs, Skype channels and IM clients) closed during the reading session
    - encouraging readers to monitor their progress against learning objectives, and to be deliberate about their understanding.
- If extended text is unavoidable, prompt the students as to how they should engage with it in the form of lead indicators (e.g., "Be sure you fully understand the context surrounding the diagram on p. 13"; "Pay specific attention to the method used in the study"; or "Be sure you understand the main reasons behind the argument. It will be helpful for you to list them").
- Scaffold the cognitive load that is appropriate for the level of the student. Recognise that students taking early courses will probably need more guidance and feedback.
- Use a clean, reading-friendly on-screen interface without clutter and distraction.
- Minimise scrolling as a reader behaviour, so that text can be read in a more stationary way.
- Be deliberate in the design of on-screen text by:
    - chunking text logically, in similar sizes as much as possible
    - preparing on-screen text to optimise the on-screen display in a reflowable manner, to maximise flexibility
    - providing as much textual land-marking as possible, including diagrams, summaries, and position indicators
    - embedding activities and additional media in the text as part of a consistent presentation

[1] Mendeley is reference-management software owned by Elsevier.

    - as a guide, providing activities every 1000 words, to provide feedback and help reinforce key ideas and concepts (excepting book chapters or articles, which frequently cannot be edited)
    - minimising in-text hyperlinks and ensuring that any used are of direct relevance.
- If PDF formats cannot be avoided or extended text cannot be edited (for example in book chapters or articles), make these resources available through a print-on-demand service, or provide versions that are easy to print.

This advice, which still stands, has the effect of reducing the cognitive load for the reading task (Rouet, 2009). Based on subsequent reading and experience, all I would add now is that we should also provide students with clear advice as to what sort of devices might most benefit them as on-screen readers (more on this below). It's also clear that we have much more to learn about what it means to read on screen.

## The issue: Screen versus print

Fundamentally, the issue is not one of screen versus print. It is whether a digital-based approach to education design would disadvantage students on the grounds that reading from a screen is inferior to reading from print. Any critique of comprehension for screen and print reading ought to consider this context of what is at stake. The issue is not whether print should be provided to distance students—it's whether designing modules to be printable serves the best interests of students, and whether a requirement for print effectively limits sound educational design, given the benefits of a digital approach (see Nichols, 2016b, pp. 34–35 for a list of advantages of an on-screen or digital education approach).

It's not unusual for advocates of digital and online education in traditional distance education organisations to be quickly—and incorrectly—misinterpreted as simply trying to do away with print (usually in the form of books that have traditionally been provided to students). As long as the issue is defined as one of "screen versus books", it's not possible to bridge the gap between the different opinions. On-screen reading is a feature, but not necessarily a requirement, of digital education. It's important to nuance just what is being usually advocated by those (like me) who are eager to point out NSD in comprehension between reading on screen and print. If I seem somewhat defensive at this point, it's because I have been misinterpreted in this way and have learned to be very careful in how I frame my advocacy for the on-screen experience.

As an aside to digital education advocates, I have no agenda to do away with print to save costs (although cost reduction is an advantage that should not be ignored). As explained in the aforementioned benefits of a digital approach, the goal is to unlock the potential of digital education in such a way that the student's likelihood of success is not compromised by having to read from a screen. If screen reading hampers comprehension, then moving from a print-based learning design approach to a digital-based one hinders student success. If there is NSD in comprehension between the two, then a much stronger (in my view, decisive) case can be made for learning design to be digital-based. That there is, in fact, NSD overall signals that educators ought to be relaxed about being more digitally focused. My initial article pointed out that learning designers can actually improve the on-screen reading experience for students by being mindful of their practice and by encouraging students to be more mindful in their on-screen reading.

To apply the various and real benefits digital tools might offer to education, the decision to base learning design on a digital rather than print foundation is fundamental. The decision for a learning design that is digital- or print-based is binary; in contemporary expressions of distance and online education, a learning design is either digital- or print-based.

- If a learning design is **print-based**, learning design decisions are limited to what can be achieved in print (which, I hasten to add, does not rule out the print being supplemented with other media). In print-based learning design a digital version might be available; however, the student experience loses nothing if the digital version is printed.
- If learning design is **digital-based**, the student gets no benefit from printing all of the required elements of study, since a significantly greater pedagogical choice and a richer series of student support data is applied to the learning experience. It's not possible to print embedded video, interactive exercises or other learning activities without breaking the flow of learning.

Although the basis of learning design is binary (either digital- or print-based), the actual mix of digital and print resources used for study in a digital-based design can be considered as a sliding scale. In a digital-based learning design the issue is not so much whether print is used, but rather what print is used for. From my understanding of the evidence available, literature supports the notion of a digital-based design with print options available where lengthy reading is required. Even in a digital-based design, print options might be reserved for articles, books, or book chapters that are narrative (i.e., where the books are not intended to also serve as learning guides, which might effectively make the entire module design a print-based one). In my view, print is perfectly appropriate for articles, book chapters, and books that are written in the format of articles, book chapters, and books. I am expressly against the notion of preparing learning guides in printable form and embedded in those formats. I am also of the view that printed forms of articles, book chapters, and books need not necessarily be offered in print as well as digitally.

In an attempt to be clearer rather than labour the point, I am saying that print can still play a part in a digital-based learning design. While everything ought to be available to students digitally, long readings (assimilative resources) might also be available in print. I am advocating a digital-based learning design in which print is not the limiting factor of what can be designed. Good practice would, in my view, provide a digital version of works over 1200 words that students could either print themselves or order through a print-on-demand service. From my understanding of the evidence there is no imperative for students to be given print at all, provided the recommendations listed earlier are applied. However, in recognition of the strong student preference still apparent in the literature, good practice would make it possible for these extended readings to be printed as well. Good practice would also encourage students to develop effective on-screen reading behaviours (including those that minimise computer vision syndrome [CVS] as outlined in the initial paper).[2] Not supplying print by default is not, in my view, evidence of bad practice.

I am conscious that I stray into matters of learning design, but in my view the matters of on-screen reading in education settings and learning design are inseparable. There is much more to learning than reading, and for learning design to be limited to what is possible to read in print is an abdication of the educator's ultimate responsibility and a denial of the true potential of digital education. Given that, in the right circumstances, there is NSD in comprehension between reading on screen and print, it follows that the benefits of digital design decisively outweigh the apparent benefits of a print-based one. (I address issues of student preference and learning to read on screen further on in this addendum.)

[2] It is often claimed that reading from a screen brings on headaches, and that many students who work with screens all day prefer print by night. This warrants a response beyond this addendum. The advice relating to CVS seems to address the issue for the most part. Adopting different advice for on-screen reading, as outlined later in this paper, might also make a positive difference. Providing a print option for extended narrative, as I suggest as good practice, does provide these students with a mechanism to address their concern. Institutions might choose to cover the costs of printing for students who claim on-screen reading is difficult (i.e., beyond preference).

## Preference for reading print

The argument that students prefer print tends to be a start-and-end point for those against a digital approach to learning design. Studies, many international in scope, continue to confirm student preference for printed materials (Baron, Calixte, & Havewala, 2017; Mizrachi, 2015; Mizrachi, Salaz, Kurbanoglu, & Boustany, 2018; Zhang & Kudva, 2014). This finding is unremarkable; the reasons students have for this preference are well defined and well understood. As mentioned in the previous section, it is still possible to make some allowances for print preference if extended reading is required. The actual issue—whether digital-based learning designs are viable for education—goes well beyond that of student preference for reading in print, and into matters of student outcomes. The further studies considered since my 2016 article serve to further nuance the general student preference for print.

One article suggests that the extent of student print preference can be quantified. In their work on e-textbooks, Terpend, Gattiker, and Lowe (2014), discovered that "10 percent of individuals will still adopt the hardcopy text even if it is priced at 3.5 times the e-text" (2014, p. 164). They also found that the price point at which all students would purchase a printed text over an electronic one is around 111.59% of the e-text price.

In my initial article, I footnoted that, at the time of writing, "there were no published studies identifying the percentage of students who prefer an on-screen-only education experience" (Nichols, 2016b, p. 35). I was incorrect. Mizrachi (2015) found that, of her respondents, "about 18% agreed or strongly agreed with a preference for reading electronically" (2015, p. 305). This nicely matches the "up to 20%" figure I included in the paper, citing Open Polytechnic findings from that same year and inferred results from a recent Open University study. Mizrachi further found that an electronic version of a reading of fewer than five pages would be preferred by 47.7% of respondents, and that almost half (49%) of doctoral students and over one-third (35%) of postgraduate students were found to prefer digital/on-screen resources over print ones. Similarly, Zhang and Kudva found that e-book adoption is positively influenced by "the number of books read, the individual's income, the occurrence and frequency of reading for research topics of interest, and the individual's Internet use, followed by other variables such as race/ethnicity, reading for work/school, age, and education" (2014, p. 1695).

It's possible that respondents to questions relating to media preference project more than just their typical reading activity into their response. For example, Baron et al. (2017) found that 65% of their sampled students (18 to 26 years) were likely to report multi-tasking while reading on screen. This may be a factor behind the 92% who reported better comprehension from print. It's also interesting to note that 35.4% of that same study's respondents preferred a digital format for shorter academic texts (slightly fewer than the number from Mizrachi above). Additional studies provide alluring insight into actual student behaviour in on-screen reading. One quote from a participant is revealing: "'Sometimes I forgot I was reading a textbook. I had to train my brain to think critically when reading because usually when I'm on a device it's for recreation'" (Dobler, 2015, p. 488). Studies have also found that 80–90% of participants reading on laptops (Mizrachi, 2015; Mizrachi et al., 2018), which are arguably not the most convenient means of engaging with on-screen reading (see 'Advice for students' below). This practice might help to explain the overwhelming rejection of on-screen reading by students. Improving students' perceptions of on-screen reading may well help them to succeed with it (Ross, Pechenkina, Aeschliman, & Chase, 2017).

It's not unusual for students to self-report reduced comprehension from on-screen reading. However, we need to be clear as to what this finding implies, because student perceptions of print being better are at odds with experimental findings that signal NSD. This is an example of subjective perception and objective data not matching. One interesting study (Kretzschmar et al.,

2013) used EEG and eye-tracking technology to test cognitive engagement with text in print, an e-reader, and a tablet device for short texts. The article clearly demonstrates the relationship between preference and performance for print and digital reading—there was NSD between the three devices, and no evidence that device reading requires more physiological effort. Deciding to not provide a digital-based learning design, or to resist it, on the grounds that students prefer print and self-report learning better from it, is indefensible on the basis of literature evidence. Students may not fully appreciate the long-term benefits of being required to do something that they do not prefer, nor understand what a digital-based approach to learning design might mean for their ultimate success. In my article I wrote that, "Effective on-screen reading skills are important for 21st century professionals" (2016b, p. 34), which can defensibly include students as they advance through their studies. Students who are confident and accomplished on-screen readers will have developed an essential professional skill that will serve them well across their studies and beyond, a skill that they will value more as they advance in their studies (Mizrachi, 2015; Zhang & Kudva, 2014).

## Further comparison study findings

Several studies reinforce the finding of NSD in comprehension from reading on screen and reading print. Chen and Catrambone (2015), for example, found NSD in their comparison of on-screen and print comprehension in treatments of 1000 words, even though there was a print preference across their sample. The authors speculate that younger readers are likely to be more confident reading from the screen, even if their preference is to read from print. It's of particular interest that the on-screen readers performed as well as the print ones, even though the print readers took more time (and more notes). In a similar study with younger (grade 10 and early university) respondents, this time in the "natural school setting and not in an artificial laboratory treatment" (Sackstein, Spark, & Jenkins, 2015, p. 4), the finding was again NSD, although students with previous experience in using iPads were able to complete the task quicker than average (with no adverse effect on their results). My own published comparison of the student experience for two versions of the same module (one in print and the other online only), also found NSD for various measures of student success (Nichols, 2016a), although it is clear that many students studying online opted to print the materials rather than read them on screen. Several treatments in yet another study, confounding participants' cognitive pressure as they read on screen and from print, also found NSD difference (Sidi, Shpigelman, Zalmanov, & Ackerman, 2017), although the authors suggest that "the lengthier the text, the more it is susceptible to the technological disadvantages associated with screen reading (e.g., eye strain)" (2017, p. 63). A small group studied in Young (2014) also found NSD, despite a clear participant preference for print and the use of substantial articles. Finally, Singer Trakhman, Alexander, and Berkowitz (2017) found NSD in overall comprehension for readings of around 550 words, but cautioned that digital readers tended to read more quickly and overestimate the effectiveness of their reading.

A study by Porion, Aparaicio, Megalakaki, Robert, and Baccino (2016) provides a useful baseline comparison for reading on screen and in print. The treatment provided the same conditions—using a large screen in place of paper and showing the same page view of 1000 words on both. The authors conclude that "if we fulfil all the conditions of paper-based versus computerized presentation (text structure, presentation on a single page, screen size, several types of questions measuring comprehension and memory performances), reading performances are not significantly different" (2016, p. 569). Requiring students to engage with on-screen text also leads towards NSD outcomes, which proved to be the case when participants were required to read and edit 600-word papers as an on-screen and print task (Eden & Eshet-Alkalai, 2013).

One study, an outlier in terms of finding in favour of print (Kim & Kim, 2013), raises a methodological issue. The conditions under which a study takes place can skew the findings. In

the case of Kim and Kim, on-screen participants were approximately 36% slower in completing the task. Further, those respondents who preferred print averaged comprehension scores of 61.59 and 79.30 for the on-screen and print reading treatments, whereas students preferring on-screen reading averaged 54.65 and 56.24 respectively. It seems from the methodology that the on-screen treatment required students to use a mouse to circle the correct answer in an electronic document (a facsimile of the paper version). The difference in average score across the two groups of 23% in a multiple-choice test in the print treatment requires more explanation than is offered in the article. Until these questions are addressed, these outlier findings are probably best ignored. It might simply be that those participants (teenagers) specifying a preference for on-screen reading were weaker readers or had access to online social media, or that those using the on-screen interface were asked to indicate their responses by drawing on the screen.

Unfortunately the Kim and Kim study is included in an otherwise excellent work of meta-analysis (Kong, Seo, & Zhai, 2018). It's not clear whether excluding the Kim and Kim study, a clear outlier, might have brought the Kong et al. summary to one of NSD. The meta-study finds "reading on paper was better than reading on screen in terms of reading comprehension" (2018, p. 138). However, the authors also conclude that, after 2013 (the year of the Kim & Kim paper), "the magnitude of the difference in reading comprehension between paper and screen followed a diminishing trajectory" (2018, p.138). The authors suggest that familiarity with print and cognitive load might explain the improvement in cognitive performance over time, giving an important indication that familiarity with on-screen reading and effective learning design can make a positive difference in equivalence.

Not all studies find NSD. One study compared student reading for approximately 450 words across various treatments (Singer & Alexander, 2017a) and found that participants reading print had greater comprehension of key points, even though participants self-reported that they thought they did better when reading digitally. In this study, while overall main-idea recall took place from the on-screen reading treatment, print provided better key point recall. In their abstract, Stoop, Kreutzer, and Kircz (2013) claimed to find in favour of print; however, the article's text concluded that results were "far from unequivocal" (p. 377), in that the print group scored better on 8 out of 24 questions (3 significantly) and scored higher overall (but not to a level of statistical significance), whereas the digital group scored better on the remaining 16 questions. The Stoop et al. study is not, strictly speaking, a comparison of on-screen and print reading, because the on-screen treatment included a virtual mind map and video clips. Ultimately, the article concludes that "[b]oth forms had advantages and disadvantages" (ibid.) Importantly Stoop et al. extend their study into learning design, which is arguably where studies must move if we are to learn more about the comparative merits of print- and digital-based education.

As the Stoop et al. study indicates, reading needn't always involve narrative text. A study comparing the ability of children in grades 1 to 6 in reading and answering questions, under time constraints, from a tablet and print, found in favour of the latter (Lenhard, Schroeders, & Lenhard, 2017). Generally, children doing the test on screen "worked faster but at the expense of accuracy" (2017, p. 427). In this study, though, children in the computer-based treatment group were not able to correct any mistakes, and there is no indication that children doing the print-based tests were able to correct their answers. A similar study (Sidi, Ophir, & Ackerman, 2016), this time without a time limitation, found NSD.

## E-textbooks

Several large-scale studies consider the (typically undergraduate) student experience with e-textbooks. A comparison study of the same module (one treatment with a commercial textbook and the other using an open-source, online text) found that using the online text increased student retention and decreased costs to students without hindering their performance (Clinton, 2018).

DeNoyelles, Raible, and Seilhamer (2015) found there are clear trends towards more student adoption of e-textbooks; another finding is that using e-textbooks considerably improves student preference for them (Dobler, 2015; Gueval, Tarnow, & Kumm, 2015). In the Dobler study, students used an e-textbook that included multimedia resources and, interestingly, 64.5% of participants reported that the e-textbook had a positive influence on their cognitive engagement. Another study found that students using printed textbooks achieved higher grades, but not to a level of significance (Terpend et al., 2014).

E-textbook adoption studies generally recommend that instructors play a key part in helping students to make good use of the opportunities these resources provide (Dobler, 2015), including the benefits of e-textbook study tools (Van Horne, Russell, & Schuh, 2016). E-textbooks can suffer from poor user-interface design (Myrberg & Wiberg, 2015), which works against their broader adoption.

## Opportunities for further primary research

Consideration of the additional works cited in this addendum shows that there are different forms and conditions of on-screen reading. Because not all on-screen reading situations are similar, or likely to be equivalent, a range of variables is possible in any comparison study.

- **There are multiple types of on-screen text**. Differences in e-text are evident in questions, briefings, learning guides, short articles, full-length articles, books, and other formats. Length is a particularly important variable. Many studies compare treatments that use materials of around 500 words. Comparison of full-size book chapters and journal articles are missing from primary studies.
- **Motivation for reading varies**. Reading aloud to a child is different to reading on a commute or studying a broad range of scholarly books for research. The reason for reading or studying a text is important and may make one or other mode of engagement (on-screen or print) more appropriate.
- **On-screen formats are multi-faceted**. An on-screen format might be an HTML page with or without hyperlinks and embedded multimedia, a free-text version of a physical book, a PDF (fixed) version of a physical book, or a scanned page. Each format has different features relating to page metaphor, user control over size and type of font, distraction (or enhancement), text search and selection, and text advance/review.
- **Interfaces vary**. The reading experience with a Kindle app differs from that with a web browser or proprietary e-textbook interface. The extent to which these provide spatial feedback, synchronisation flexibility, and highlight/annotation options can differ markedly.
- **Devices vary**. The reading experience is different for e-text from a laptop screen, desktop monitor, Kindle, iPad and smartphone.

Further primary research is needed across these permutations to provide a fuller picture of equivalence, and to provide clues as to which combinations might be optimal. An important article by Mangen and van der Weel (2016) should also be considered by researchers, as the authors define further dimensions of reading that are not adequately explored in the studies reviewed to date. Defining reading is also a concern raised by Singer and Alexander (2017b), who propose that NSD findings are most consistent in treatments of up to 500 words (I proposed 1200 in my initial article). Their claim, “when longer texts [than 500 words] are involved or when individuals are reading for depth of understanding and not solely for gist, print appears to be the more effective processing medium” (2017b, p. 1033), needs empirical confirmation.

Beyond the immediate concern of on-screen and print reading, experimental studies comparing student performance with print-based and digital-based learning designs are also pertinent to the

concern of the initial article. The methodology I used (Nichols, 2016a) could be applied under similar circumstances to advance thinking about the binary difference of learning design decisions.

## Advice for students

After considering the articles reviewed for this addendum, I am left with the impression that not enough is being done to assist students to constructively engage with on-screen reading options in their studies and when participating in comparative studies. Mizrachi et al. are correct to suggest that "[i]nstructional designers could work towards helping students acquire the prerequisite knowledge to leverage digital texts through more explicit instruction on the navigation of e-formats" (2018, p. 28).

More can be done to reassure students that a requirement for on-screen reading is, ultimately, to their advantage as 21st century learners and will better serve them as they advance to postgraduate study. On-screen reading skills can also extend to students developing digital workflows, which might include using bibliographic software (such as Mendeley and Zotero) for categorising, storing, annotating, and otherwise studying articles; Trello for planning assignments and study sessions; and other applications for task management and note-taking. Most of these solutions now synchronise seamlessly across devices and work well offline (with the exception of Trello). More can be done to encourage students to become conscious on-screen readers who purposefully remove distractions as they read, deliberately read more slowly, and learn to apply highlighting and note-taking tools. Students might also be better informed about how digital-based learning design can improve their overall study workflow.

I suspect that advocates of on-screen reading are also leaving the actual reading device used by students to chance. That 80–90% of students read on screen using a laptop gives pause for thought, as laptops are neither as portable, nor as flexible to use, as tablet devices. In one of my blog posts related to this article ("A Further Update to 'Reading and Studying From the Screen'") I describe my own on-screen reading setup, which is designed to maximise flexibility and a seamless transition from reading, to studying, to writing on the same device (in my case a Microsoft Surface 3) in different configurations. My on-screen reading behaviour is reinforced by including Mendeley, OneNote, and online library access in my workflow, and I have learned to close email, Twitter, and social media access as I read and study.

## Conclusion

Consideration of further literature related to on-screen and print reading since the article, "Reading and Studying on the Screen: An Overview of Literature Towards Good Learning Design Practice", was published provides a richer understanding of the subject, but little change to my recommendations. The results of comparison studies remain mixed, tending towards NSD, with evidence that the effectiveness and experience of on-screen reading can be improved through learning design practice.

As more module developers and universities shift towards digital-based learning design, student success and the student experience can be enhanced through the advice offered in the initial 2016 article and this addendum. Importantly, new imperatives for research and a better range of advice for students needing to engage with on-screen reading can now be confidently suggested. Testing across variables including type of on-screen text, motivation for reading, on-screen format, and interface and device will help to extend knowledge further.

Ultimately, the issue is not so much screen versus paper, but how we might create the conditions in which studying on screen becomes at least equivalent to studying print materials, so that we

can confidently adopt a digital-designed approach to learning design. If we adopt a digital-based design we can unlock an entire suite of support and learning activity possibilities that would not otherwise be optimally provided (Ross et al., 2017). That there is, overall, NSD in reader comprehension for screen and print formats should increase our courage for removing print as a constraint to further developing educational systems.

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