DHSI

DIGITAL HUMANITIES SUMMER INSTITUTE

eTextBook Publishing and Open Educational Resources on the Web and Mobile Devices

Olin Bjork and Inba Kehoe

ETCL
ELECTRONIC TEXTUAL CULTURES LAB

Social Sciences and Humanities Research Council of Canada
Conseil de recherches en sciences humaines du Canada

Welcome to DHSI 2023!

Thank you for joining the DHSI community!

In this coursepack, you will find essential workshop materials prefaced by some useful general information about DHSI 2023.

Given our community's focus on things computational, it will be a surprise to no one that we might expect additional information and materials online for some of the workshops—which will be made available to you where applicable—or that the most current version of all DHSI-related information may be found on our website at dhsi.org. Do check in there first if you need any information that's not in this coursepack.

Please also note that materials in DHSI’s online workshop folders could be updated at any point. We recommend checking back on any DHSI online workshop folder(s) that have been shared with you in case additional materials are added as DHSI approaches and takes place.

And please don't hesitate to be in touch with us at **institut@uvic.ca** or via Twitter at **@AlyssaA_DHSI** or **@DHInstitute** if we can be of any help.

We hope you enjoy your time with us!

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Statement of Ethics & Inclusion

Please review the DHSI Statement of Ethics & Inclusion available here: **https://dhsi.org/statement-of-ethics-inclusion/**

DHSI is dedicated to offering a safe, respectful, friendly, and collegial environment for the benefit of everyone who attends and for the advancement of the interests that bring us together. There is no place at DHSI for harassment or intimidation of any kind.

By registering for DHSI, you have agreed to comply with these commitments.

Virtual Sessions

Your registration in DHSI 2023 also includes access to the virtual **institute lecture** sessions. Access details for these talks will be shared as DHSI approaches.

Due to the high volume of attendees, please ensure your DHSI registration name or DHSI preferred name and your Zoom name match so that we know to let you into the virtual sessions.

DHSI Materials

DHSI materials (ex. videos, documents, etc.) are intended for registrant use only. By registering, you have agreed that you will not circulate any DHSI content. If someone asks you for the materials, please invite them to complete the registration form to request access or contact us at **institut@uvic.ca**.

Auditor and participant registration

If you registered to **audit** any workshops, note that auditor involvement is intended to be fully self-directed without active participation in the workshop. The auditor option offers more flexibility regarding pace and time with the workshop content. Your registration as an auditor will include access to some asynchronous workshop materials only and does not include access to live workshop sessions and/or individual/group instruction or consultation. Please direct any questions about DHSI workshop auditing to **institut@uvic.ca**.

If you registered as a **participant** in any workshops, your registration includes access to asynchronous content + active participation in live workshop session(s). The workshop instructor(s) will contact you about the date(s), time(s), and platform(s) of the live workshop session(s).

If you are unsure whether you registered as an auditor or participant, please check your registration confirmation email. Further questions can be directed to **institut@uvic.ca**.

Schedule

The at-a-glance schedule of DHSI 2023 courses, workshops, institute lectures and aligned conferences & events can be found here:
https://dhsi.org/timetable/

All times are listed in North American **Pacific Time Zone**.

For those who registered as participants in any workshops, live sessions for online workshops are not currently listed on the above-referenced schedule. **Instructors will be in touch with registered participants directly about the exact date(s) and time(s) of their live workshop session(s).**

Acknowledgements

We would like to thank our partners and sponsors (including the Social Sciences and Humanities Research Council), workshop instructors, aligned conference & event organizers, institute lecturers, local facilitators, and beyond for making this possible.

Further information

General DHSI 2023 information: **https://dhsi.org/program/**

Full course listings (in-person): **https://dhsi.org/on-campus-courses/**

Full workshop listings (online): **https://dhsi.org/online-workshops/**

Aligned conferences & events (in-person): **https://dhsi.org/on-campus-aligned-conferences-events/**

Aligned conferences & events (online): **https://dhsi.org/online-aligned-conferences-events/**

Institute lectures: **https://dhsi.org/institute-lectures/**

Frequently asked questions: **https://dhsi.org/faq/**

Any questions not addressed in the above pages? Please email us at **institut@uvic.ca**!

eTextBook Publishing and Open Educational Resources on the Web and Mobile Devices

Digital Humanities Summer Institute 2022
Instructors: Olin Bjork and Inba Kehoe

Welcome!

This workshop will brainstorm ideas for new or ongoing eTextbook or Open Educational Resource (OER) projects proposed by participants in advance and discuss models, best practices, and platform options for these projects. The 2021 offering consisted of three two-hour discussions of our coursepack readings and examples of eTextbooks and OER that illustrate the readings, acting as a foundation for a coming in-person, hands-on course for those who want to author or compile an eTextbook that is multimodal, interactive, and usable on mobile phones and tablets as well as laptops and desktops. Course topics include writing for students and general audiences, obtaining and reusing content from OER, integrating and synchronizing multimedia assets, designing usable and accessible interfaces, licensing and copyrighting materials, choosing the right formats and distribution channels, marketing and promoting an eTextbook, and using eTextbooks for pedagogical purposes such as annotation, assessment, or conducting a class project in which students create their own eTextbook(s).

If you have any questions or concerns, please do not hesitate to reach out to Olin or Inba.

Course Schedule

eTextBook Publishing and Open Educational Resources on the Web and Mobile Devices

Date	**Activity**	**Preparation**
Friday 6/3	Post your proposal to the workshop's discussion forum. A link to this forum, guidelines for the proposal, and a list of helpful resources will be emailed to workshop participants by mid-May.	*Recommended:* read some or all of the readings in this coursepack.
Friday 6/10 (9:30am-12:30pm PDT)	Synchronous discussion of proposals via Zoom. A Zoom meeting invitation will be emailed to workshop participants before DHSI begins.	*Required:* Read the proposals your classmates have posted to the workshop's discussion forum and share your thoughts or suggestions by replying to some or all of them.

Openability

Introduction

The two readings in this section are a 2017 chapter by Cable Green and a 2018 journal article by David Wiley and John Hilton. They are intended to foster a discussion of the importance of open licensing for open educational resources (OER) and how these licenses and resources guide us towards an OER-enabled pedagogical approach. You will learn how Creative Commons (CC) licenses give copyright holders a way to grant the public permission to use their copyrighted works in prescribed ways. The readings will prepare you to discuss theories and examples of how we can develop an OER-enabled pedagogical environment that benefits students in the classroom and increases the quantity and quality of OER available for the public good.

Green, C. (2017). Open licensing and open education licensing policy. In Jhangiani, R. S. & Biswas-Diener, R. (Eds.), *Open: The philosophy and practices that are revolutionizing education and science* (pp. 29-41). Ubiquity Press. License: CC-BY 4.0. URL: https://www.ubiquitypress.com/site/chapters/10.5334/bbc.c/download/591/ or https://www.ubiquitypress.com/site/books/10.5334/bbc/read/?loc=010.xhtml

Green (2017) provides a primer on why and how we can leverage open licensing to expand access to free, high-quality OER. The Hewlett Foundation defines OER as “teaching, learning, and research resources [digital or otherwise] that reside in the public domain or have been released under an intellectual property license that permits their free use and repurposing by others.” While existing copyright law restricts the use of protected works to “fair dealing” or “fair use,” open licensing (via a Creative Commons license) gives individual creators/authors a way to grant the public copyright permissions to legally use, modify, and/or share their creative work(s). Creative Commons licenses help creators assert and enforce their copyright and ensure that authors are credited for their work for as long as their copyright lasts. In the latter half of the chapter, Green explores how policy makers can leverage open licensing to solve some of the problems currently existing for members of the public who are looking for equitable access to high-quality educational resources.

As you read the chapter, please reflect on which CC license best suits your purposes.

Wiley, D., & Hilton, J. (2018). Defining OER-enabled pedagogy. *International Review of Research in Open and Distributed Learning 19*(4), 133-147. http://www.irrodl.org/index.php/irrodl/article/view/3601/4724

Wiley and Hilton (2018) coin the term OER-*enabled pedagogy* to describe their approach, arguing that other "open" terms (e.g., *open pedagogy* and *open educational practices*) have become too imprecise. In an open-enabled pedagogical environment, learning materials have licenses that allow everyone the right to use them for the "5R activities," namely to retain, reuse, revise, remix, and redistribute these materials. Open-enabled teaching and learning practices are those that are only possible within the context of the 5Rs. Only then can students be "free to engage in a broader range of activities [and] … learn in a border range of ways." The authors provide a set of criteria for determining the extent to which teaching and learning practices qualify as OER-enabled pedagogy.

As you read the article, please reflect on which of your practices qualify as OER-enabled pedagogy.

Efficacy

Introduction

The two readings in this section are a 2019 article by Virginia Clinton and Shafiq Khan and a 2019 article by Johnny B. Allred and Cheryl Ann Murphy. These articles are grounded in experimental and empirical research on the effectiveness of electronic textbooks. They are intended to complement the more theoretical and philosophical articles in the openability section by putting to test the essential claim or hypothesis that the adoption of open textbooks by instructors will benefit student learning.

Clinton, V., & Khan, S. (2019). Efficacy of open textbook adoption on learning performance and course withdrawal rates: A meta-analysis. *Aera Open 5*(3), 1-20. https://doi.org/10.1177/2332858419872212

This is the most recent (as of this writing) of several meta-analyses of the efficacy of open textbooks. A *meta-analysis* generates statistics from the combined results of multiple research studies on a given topic and then uses these statistics to draw conclusions and make recommendations. We chose to include a meta-analysis because it is a convenient way to obtain a birds-eye view of research conducted on the effectiveness of open textbooks. Unless you have a background and interest in statistics, feel free to skim or ignore the authors' documentation of their statistical procedures and programming code.

As you read the article, please

1. Reflect on the implications of the authors' findings and recommendations and note any gaps in the data and/or oversights in their interpretation of the data
2. Consider how you might structure a future study of the efficacy or perception of open textbooks and/or OER in a course taught by you and/or others at your institution

Allred, J. B., & Murphy, C. A. (2019). Interactive electronic textbook use in higher education: grades, engagement, and student perceptions. *International Journal of Innovation and Learning, 25*(3), 296-309. https://dx.doi.org/10.1504/IJIL.2019.098895

Whereas Clinton and Kahn (2019) measure the impact of openness and do not assume any functional or practical differences between open and commercial textbooks, Allred & Murphy (2019) measures the impact of interactivity in the case of a single commercial electronic textbook with interactive features that would not be feasible in a print textbook.

As you read this study, please reflect on what beneficial affordances an electronic textbook might offer aside from the potential of being freely or openly available.

Multimodality and Accessibility

Introduction

Commercial textbooks tend to be heavily illustrated, even though these illustrations make the books more expensive. Clearly, for-profit textbook publishers have determined that the return on illustrations is greater than the investment. But when you make the decision to design or choose an OER, your rationale for illustrations should be practical rather than financial. Fundamental questions about the purpose of illustrations need to be revisited. For instance, do teachers and students want illustrations in learning materials because they make them more pedagogically effective or because they make them more visually appealing? In either case, the content of illustrations is not directly accessible to people who cannot see them. To make OERs that are accessible to the widest possible audience, including people who use screen readers and other assistive technologies, designers may need to include audio and/or video in addition to text and/or images. The readings in this section, a 2016 document by Dave Gunn and a 2019 chapter by Richard Mayer, suggest approaches and rationales for designing or choosing accessible multimedia formats and interfaces.

Gunn, D. (2016). *Accessible eBook guidelines for self-publishing authors*. Accessible Books Consortium.

https://www.accessiblebooksconsortium.org/export/abc/abc_ebook_guidelines_for_self-publishing_authors.pdf

Gunn (2016) discusses different types of disabilities and various eBook formats that you may want to consider when designing or choosing accessible electronic textbooks. The article is intended for self-publishers, so it also includes a section on how to construct accessible source documents that will later be converted to one or more eBook formats.

As you read this document, please

1. Think about what updates to its coverage of disabilities and formats you could suggest and share with the class
2. Think about any disability-related policies in your region that you would need to be aware of when developing an OER

Mayer, R. (2019). How multimedia can improve learning and instruction. In Dunlosky, J. & Rawson, K. (Eds.), *The Cambridge handbook of cognition and education* (Cambridge Handbooks in Psychology, pp. 460-479). Cambridge University Press. doi:10.1017/9781108235631.019

Mayer (2019) summarizes 12 principles for multimedia learning materials in both print and electronic formats and goes over the research evidence for each principle as well as its applicability to different students, materials, and subject matters. The 12 principles derive from his "cognitive theory of multimedia learning," which holds that when a concept is presented to learners in verbal *and* visual modalities, learners cognitively construct verbal *and* pictorial representations of the concept that are then integrated with each other and with related background knowledge to form a mental encoding of the concept that is more robust and retrievable than it would have been if the concept had been presented in a single modality.

As you read this chapter, please think about how the textbooks and other learning materials that you use might do a better job of incorporating these principles.

Open Licensing and Open Education Licensing Policy

Cable Green

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Editors' Commentary

It would not be an overstatement to say that Creative Commons licenses provide the legal foundation for most of the open education movement. These licenses—free and easy to apply—provide educators, scholars, and artists the language with which to share their work on their own terms. In this chapter, author Cable Green provides a primer on the licenses themselves before going on to explore how public policymakers can leverage open licensing policies to effectively combat a range of challenges including high textbook costs and publicly-funded-yet-paywalled research.

Introduction

I work at Creative Commons (CC), as the Director of Open Education, because I seek to create a world in which the public has free, legal and unfettered access to effective, high quality education and research resources, and learning opportunities. I've spent my career working in post-secondary education and have seen students: take fewer courses because of the high cost of textbooks, go without required educational resources due to cost, and graduate with tens of thousands in debt. After learning about 'open education,' I decided to join the movement and help more learners access affordable, meaningful learning opportunities.

How to cite this book chapter:

Green, C. 2017. Open Licensing and Open Education Licensing Policy. In: Jhangiani, R S and Biswas-Diener, R. (eds.) *Open: The Philosophy and Practices that are Revolutionizing Education and Science.* Pp. 29–41. London: Ubiquity Press. DOI: https://doi.org/10.5334/bbc.c. License: CC-BY 4.0

Open education is an idea, a set of content and a community which, properly leveraged, can help everyone in the world access free, high quality, open learning materials for the marginal cost of zero. We live in an age of information abundance where everyone, for the first time in human history, can potentially attain all the education they desire. The key to this sea change in learning is Open Educational Resources (OER). OER are educational materials that are distributed at no cost with legal permissions for the public to freely use, share, and build upon the content. The Hewlett Foundation defines OER as teaching, learning, and research resources that reside in the public domain or have been released under an intellectual property license that permits their free use and re-purposing by others.[1] OER are possible because:

- educational resources are digital[2] and digital resources can be stored, copied, and distributed for near zero cost;
- the internet makes it simple for the public to share digital content; and
- Creative Commons licenses (and public domain tools) make it simple and legal to keep one's copyright and legally share educational resources with the world.

Today we can share effective education materials with the world for near zero cost. As such, I argue educators and governments supporting public education have a moral and ethical obligation to do so. After all, education is fundamentally about sharing knowledge and ideas. I believe OER will replace much of the expensive, proprietary content used in academic courses – it's only a matter of time. Shifting to this model will generate more equitable economic opportunities globally and social benefits without sacrificing quality of educational content. In this chapter, I will first discuss how 'open licensing' works and why it is a critical part of OER. We will then explore how and why governments and foundations (funders) are starting to use open educational licensing policies to require open licenses on educational resources they fund.

Open Licensing

Long before the internet was conceived, copyright law regulated the very activities the internet, cheap disc space and cloud computing make essentially free (copying, storing, and distributing). Consequently, the internet was born at a severe disadvantage, as preexisting copyright laws discouraged the public from realizing the full potential of the network.

Since the invention of the internet, copyright law has been 'strengthened' to further restrict the public's legal rights to copy and share on the internet[3]. For example, in 2012 the US Supreme Court on upheld the US Congress's right to extend copyright protection to millions of books, films, and musical compositions by foreign artists that once were free for public use. Lawrence Golan, a

University of Denver music professor and conductor who challenged the law on behalf of fellow conductors, academics and film historians said 'they could no long afford to play such works as Sergei Prokofiev's "Peter and the Wolf," which once was in the public domain but received copyright protection that significantly increased its cost.'[4]

While existing laws, old business models, and education content procurement practices make it difficult for teachers and learners to leverage the full power of the internet to access high-quality, affordable learning materials, OER can be freely retained (keep a copy), reused (use as is), revised (adapt, adjust, modify), remixed (mashup different content to create something new), and redistributed (share copies with others)[5] without breaking copyright law. OER allow the full technical power of the internet to be brought to bear on education. OER allow exactly what the internet enables: free sharing of educational resources with the world.[6]

What makes this legal sharing possible? Open licenses. The importance of open licensing in OER is simple. The key distinguishing characteristic of OER is its intellectual property license and the legal permissions the license grants the public to use, modify, and share it. If an educational resource is not clearly marked as being in the public domain or having an open license, it is not an OER. Some educators think sharing their digital resources online, for free, makes their content OER – it does not. Though it is OER if they go the extra step and add an open license to their work.

The most common way to openly license copyrighted education materials – making them OER – is to add a Creative Commons[7] license to the educational resource. CC licenses are standardized, free-to-use, open copyright licenses that have already been applied to more than 1.2 billion copyrighted works across 9 million websites.[8]

Collectively, CC licensed works constitute a class of educational works that are explicitly meant to be legally shared and reused with few restrictions. David Bollier writes:

> 'Like free software, the CC licenses paradoxically rely upon copyright law to legally protect the commons. The licenses use the rights of ownership granted by copyright law not to exclude others, but to invite them to share. The licenses recognize authors' interests in owning and controlling their work — but they also recognize that new creativity owes many social and intergenerational debts. Creativity is not something that emanates solely from the mind of the "romantic author," as copyright mythology has it; it also derives from artistic communities and previous generations of authors and artists. The CC licenses provide a legal means to allow works to circulate so that people can create something new. Share, reuse, and remix, legally, as Creative Commons puts it.'[9]

While custom copyright licenses can be developed to facilitate the development and use of OER, it may be easier to apply free-to-use, global standardized

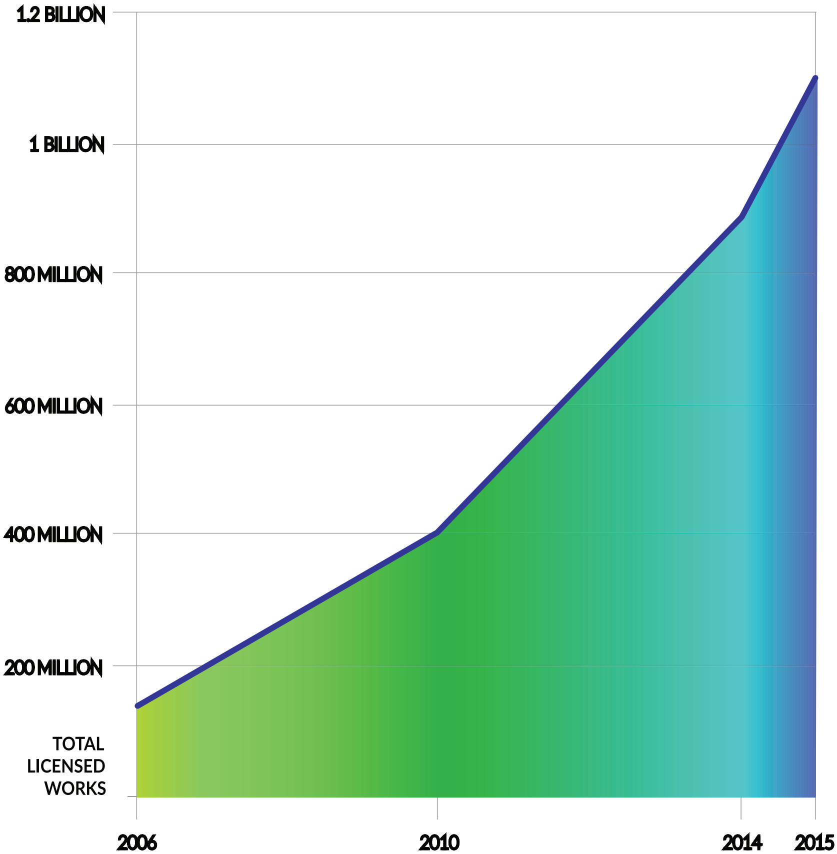

Fig. 1: Annual Growth of CC licensed works.

licenses developed specifically for that purpose, such as those developed by Creative Commons.[10]

Creative Commons Licenses

Because definitions of OER place such an emphasis on copyright permissions and licensing, a basic understanding Creative Commons licenses is critical to understanding OER. CCs open copyright licenses and tools forge a balance – allowing copyright holders to share their work – inside the traditional 'all rights reserved' setting that copyright law creates. CC licenses give everyone from individual creators to large companies and institutions a simple, standardized way to grant copyright permissions to their creative work.

All Creative Commons licenses have many important features in common:

- Every CC license helps creators retain copyright while allowing others to copy, distribute, and make some uses of their work – at least non-commercially.
- Every CC license also ensures licensors get the credit (attribution) for their work.
- Every CC license works around the world and lasts as long as applicable copyright lasts (because they are built on copyright).

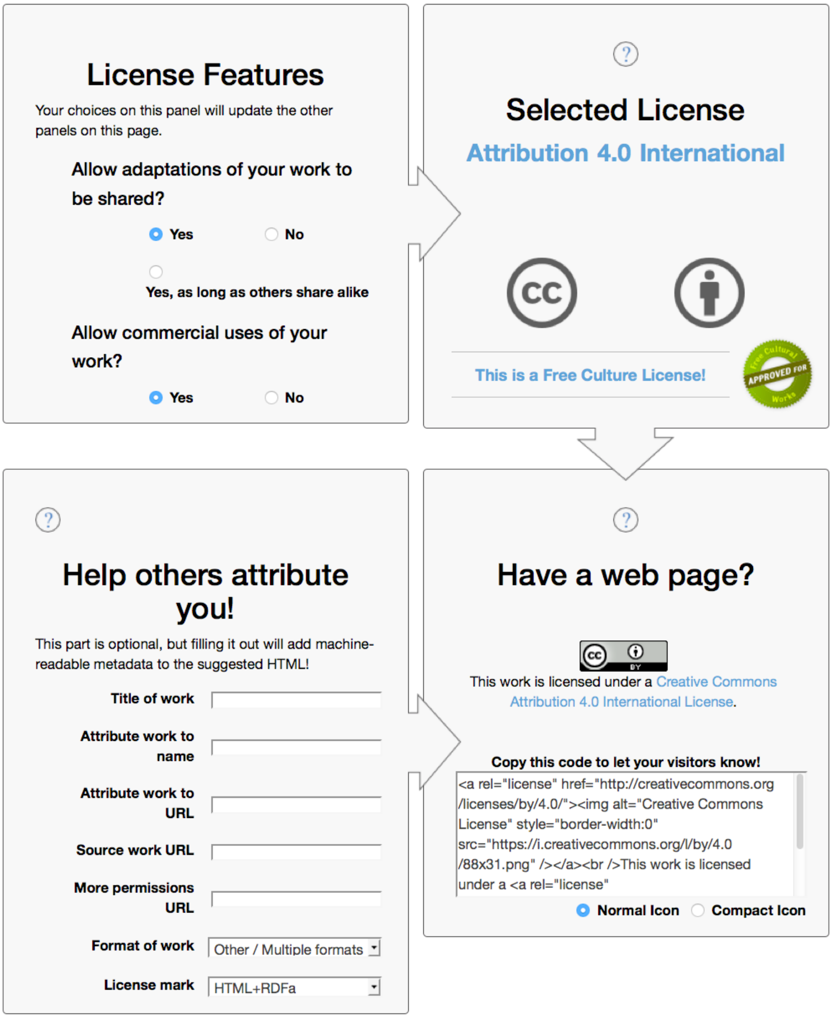

Fig. 2: Registering a CC licensee.

These common features serve as the baseline, on top of which authors can choose to grant additional permissions when deciding how they want their work to be used.

CC licenses do not affect freedoms that the law grants to users of creative works otherwise protected by copyright, such as exceptions and limitations to copyright law like fair dealing or fair use rights. CC licenses require the public to get permission to do any of the things with a work that the law reserves exclusively to a copyright holder and that the license does not expressly allow. Users of a CC licensed work must credit the author; keep copyright notices intact on all copies of the work, and link to the CC license deed (e.g., CC BY 4.0) from copies of the work. Users of CC licensed works also cannot use technological measures to restrict access to the work by others. For example, I cannot lock down your CC licensed music with digital rights management software to restrict others' use.

Anyone can get their CC license – at no cost – at CC's license chooser: http://creativecommons.org/choose It is worth mentioning there is no need to register your work to get a CC license.

The Licenses[11]

Fig. 3: The CC-BY license.

Attribution: CC BY

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This license lets others distribute, remix, tweak, and build upon your work, even commercially, as long as they credit you for the original creation. This is the most accommodating of licenses offered. Recommended for maximum dissemination and use of licensed materials. This is the license required by the US Department of Labor on all of their grants, the Campus Alberta OER initiative,[12] BC Open Textbooks Project,[13] and hundreds of other OER projects around the world. CC BY is recommended for most open licensing policies, and for OER when the author wants to maximize reuse and remix of their work.

Fig. 4: The CC-BY-Share Alike license.

Attribution-ShareAlike: CC BY-SA

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Fig. 5: The CC-BY-Non Commercial Use license.

Attribution-NonCommercial: CC BY-NC

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Fig. 6: The CC-BY-Non Commercial Use-Share Alike license.

Attribution-NonCommercial-ShareAlike: CC BY-NC-SA

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This license lets others remix, tweak, and build upon your work non-commercially, as long as they credit you and license their new creations under the identical terms. MIT's OpenCourseWare project and the Khan Academy both use this license.

Fig. 7: The CC-BY-No Derivative works license.

Attribution-NoDerivs: CC BY-ND

View License Deed | View Legal Code

This license allows for redistribution, commercial and non-commercial, as long as it is passed along unchanged and in whole, with credit to you. This is not an OER compatible open license because the ND clause doesn't allow others to revise or remix the work.

Fig. 8: The CC-BY-Non Commercial Use- No Derivative works license.

Attribution-NonCommercial-NoDerivs: CC BY-NC-ND

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This license is the most restrictive of our six main licenses, only allowing others to download your works and share them with others as long as they credit you, but they cannot change them in any way or use them commercially. This is not an OER compatible open license because the ND clause does not allow others to revise or remix the work.

CC also provides tools that work in the 'all rights granted' space of the public domain. CCs CC0 tool allows licensors to waive all rights and place a work in the public domain, and the Public Domain Mark allows any web user to 'mark' a work as being in the public domain.

For OER, the use of CC licenses looks like this:

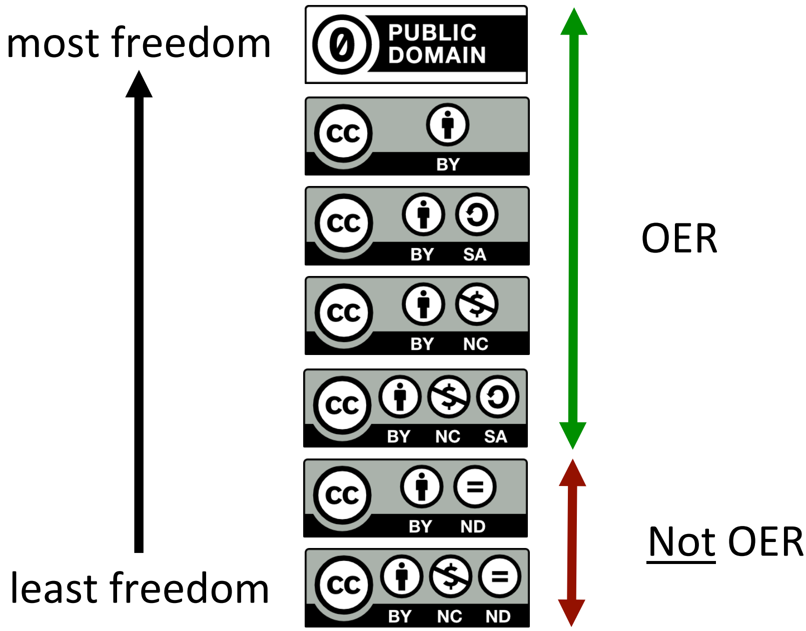

Fig. 9: CC licenses arranged from most to least permissive.

The two CC No Derivatives (ND) are not OER compatible licenses because they do not let the public revise or remix an educational resource. Because the ND licenses violate the 5Rs and every major OER definition, the open education movement does not call ND licensed educational resources 'OER.'

Now that we know what OER is and the role of open licensing in making OER 'open,' the next question is how to make OER the default content produced, adopted, used, and revised in education.

Open Education Licensing Policy

This section explores how public policymakers can leverage open licensing policies, and by extension OER, as a solution to high textbook costs, out-of-date educational resources and disappearing access to expensive, DRM[14] protected e-books. Education policy is about solving education problems for the public. If one of the roles of government is to ensure all of its citizens have access to effective, high-quality educational resources, then governments ought to employ current, proven legal, technical, and policy tools to ensure the most efficient and impactful use of public education funding.

Open education policies are laws, rules, and courses of action that facilitate the creation, use or improvement of OER. While this chapter only deals with open education licensing policies, there has also been significant open education resource-based (allocate resources directly to support OER), inducement (call for or incentivize actions to support OER), and framework (create pathways or remove barriers for action to support OER) open education policy work.[15]

Open education licensing policies insert open licensing requirements into existing funding systems (e.g., grants, contracts, or other agreements) that create educational resources, thereby making the content OER, and shifting the default on publicly funded educational resources from 'closed' to 'open.' This is a particularly strong education policy argument: if the public pays for education resources, the public should have the right to access and use those resources at no additional cost and with the full spectrum of legal rights necessary to engage in 5R activities.

My friend David Wiley likes to say 'if you buy one, you should get one.' David, like most of us, believes that when you buy something, you should actually get the thing you paid for. Provincial/state and national governments frequently fund the development of education and research resources through grants funded with taxpayer dollars. In other words, when a government gives a grant to a university to produce a water security degree program, you and I have already paid for it. Unfortunately, it is almost always the case that these publicly funded educational resources are commercialized in such a way that access is restricted to those who are willing to pay for them a second time. Why should we be required to pay a second time for the thing we've already paid for?[16]

Governments and other funding entities that wish to maximize the impacts of their education investments are moving toward open education licensing policies. National, provincial/state governments, and education systems all play a critical role in setting policies that drive education investments and have an interest in ensuring that public funding of education makes a meaningful, cost-effective contribution to socioeconomic development. Given this role, these policy-making entities are ideally positioned to require recipients of public funding to produce educational resources under an open license.

Let us be specific. Governments, foundations, and education systems/institutions can and should implement open education licensing policies by requiring open licenses on the educational resources produced with their funding. Strong open licensing policies make open licensing mandatory and apply a clear definition for open license, ideally using the Creative Commons Attribution (CC BY) license that grants full reuse rights provided the original author is attributed.

The good news is open education policies are happening! In June 2012, UNESCO convened a World OER Congress and released a 2012 Paris OER Declaration, which included a call for governments to 'encourage the open licensing of educational materials produced with public funds.'[17] UNESCO will be convening a second World OER Congress in Slovenia in 2017 to establish a 'normative instrument on OER.' OECD recently released its 2015 report: 'Open Educational Resources: A Catalyst for Innovation'[18] provides policy options to governments such as: 'Regulate that all publically funded materials should be OER by default. Alternatively, the regulation could state that new educational resources should be based on existing OER, where possible ("reuse first" principle).'[19]

As governments and foundations move to require the products of their grants and/or contracts be openly licensed, the implementation stage of these policies critical; open licensing policies should have systems in place to ensure that grantees comply with the policy, properly apply an open license to their work, and share an editable, accessible version of the OER in a public OER repository.[20]

A good example of an open education licensing policy done well is the US Department of Labor's 2010 Trade Adjustment Assistance Community College and Career Training Grant Program (TAACCCT) which committed US$2 billion in federal grant funding over four years to 'expand and improve their ability to deliver education and career training programs' (p.1). The intellectual property section of the grant program description requires that all educational materials created with grant funding be licensed under the Creative Commons Attribution (CC BY) license, and the Department required its grantees to deposit editable copies of the CC BY OER into skillscommons.org – a public open education repository.

A number of other nations, provinces and states have also adopted or announced open education policies relating to the creation, review, remix and/or adoption of OER. The Open Policy Registry[21] lists over 130 national, state, province, and institutional policies relating to OER, including policies like a national open licensing framework and a policy explicitly permitting public school teachers to share materials they create in the course of their employment under a CC license.

New open policy projects like the Open Policy Network[22] and the Institute for Open Leadership[23] are well positioned to foster the creation, adoption, and implementation of open policies and practices that advance the public good by supporting open policy advocates, organizations, and policy makers, connecting open policy opportunities with assistance, and sharing open policy information.

Because the bulk of education and research funding comes from taxpayer dollars, it is essential to create, adopt and implement open education licensing policies. The traditional model of academic research publishing borders on scandalous. Every year, hundreds of billions in research and data are funded by the public through government grants, and then acquired at no cost by publishers who do not compensate a single author or peer reviewer, acquire all copyright rights, and then sell access to the publicly funded research back to the University and Colleges. In the US, the combined value of government, non-profit, and university-funded research in 2013 was over US$158 billion[24] — about a third of all the R&D in the United States that year.

As governments move to require open licensing policies, hundreds of billions of dollars of education and research resources will be freely and legally available to the public that paid for them. Every taxpayer – in every country – has a reasonable expectation of access to educational materials and research products whose creation tax dollars supported.

Conclusion

If we want OER to go mainstream; if we want a complete set of curated OER for all grade levels, in all subjects, in all languages, customized to meet local needs; if we want significant funding available for the creation, adoption and continuous updating of OER – then we need (1) universal awareness of and systematic support for open educational resources and (2) broad adoption of open education licensing policies. When all educators are passionate about free and open access to their educational resources, when we change the rules on the money, when the default on all publicly funded educational resources is 'open' and not 'closed,' we will live in a world where everyone can attain all the education they desire.

Notes

1. Hewlett Foundation: Open Educational Resources page: http://www.hewlett.org/programs/education/open-educational-resources.
2. Most OER are 'born' digital, thought OER can be made available to students in both digital and printed formats. Of course, digital OER are easier to share, modify, and redistribute, but being digital is not what makes something an OER or not.
3. Trans-Pacific Partnership Would Harm User Rights and the Commons: https://creativecommons.org/campaigns/trans-pacific-partnership-would-harm-user-rights-and-the-commons/
4. Washington Post: Supreme Court: Copyright can be extended to foreign works once in public domain. Robert Barnes: https://www.washingtonpost.com/politics/supreme-court-copyright-can-be-extended-to-foreign-works-once-in-public-domain/2012/01/18/gIQAbqbr8P_story.html.
5. https://www.opencontent.org/definition/.
6. Game Changers: Chapter 6: Why Openness in Education? https://library.educause.edu/resources/2012/5/chapter-6-why-openness-in-education.
7. For a short history of Creative Commons see: https://creativecommons.org/about/history/; for a full history on CC read: Viral Spiral – How the Commoners Built a Digital Republic of Their Own – David Bollier: http://bollier.org/viral-spiral-how-commoners-built-digital-republic-their-own.
8. 2015 State of the Commons report: https://stateof.creativecommons.org/2015/.

[9] Viral Spiral – How the Commoners Built a Digital Republic of Their Own – David Bollier: http://bollier.org/viral-spiral-how-commoners-built-digital-republic-their-own.

[10] Note that Creative Commons (CC) licenses that include an ND clause (i.e., no derivatives) are not considered OER. For more information about CC licenses see: https://creativecommons.org/licenses/. For information about Open Source Initiative-approved licenses for software, see: https://opensource.org/licenses.

[11] https://creativecommons.org/licenses.

[12] http://albertaoer.com.

[13] https://bccampus.ca/open-textbook-project.

[14] Digital rights management (DRM) schemes are used to restrict access to and use and/or modification of copyrighted works.

[15] For a full description of all four types of open education policies, see: Nicole Allen and Nick Shockey's 2014 Open Education Conference paper: Open Educational Resources and Public Policy: Overview and Opportunities http://conference.oeconsortium.org/2014/wp-content/uploads/2014/02/Paper_59-Policy.pdf.

[16] Game Changers: Chapter 6: Why Openness in Education? https://library.educause.edu/resources/2012/5/chapter-6-why-openness-in-education.

[17] 2012 Paris OER Declaration: http://www.unesco.org/new/en/communication-and-information/events/calendar-of-events/events-websites/World-Open-Educational-Resources-Congress.

[18] OECD Open Educational Resources: A Catalyst for Innovation: http://www.oecd.org/edu/open-educational-resources-9789264247543-en.htm.

[19] Page 131.

[20] For more detail on what governments should consider when implementing an open education licensing policy, see CCs 'Open Licensing Policy Toolkit' https://blog.creativecommons.org/2015/09/22/open-licensing-policy-toolkit-draft/.

[21] http://oerpolicies.org.

[22] https://openpolicynetwork.org.

[23] https://openpolicynetwork.org/iol.

[24] http://www.nsf.gov/statistics/2015/nsf15330/.

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Defining OER-Enabled Pedagogy

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Abstract

The term “open pedagogy” has been used in a variety of different ways over the past several decades. In recent years, its use has also become associated with Open Educational Resources (OER). The wide range of competing definitions of open pedagogy, together with its semantic overlap with another underspecified term, open educational practices, makes it difficult to conduct research on the topic of open pedagogy. In making this claim we do not mean to cast doubt on the potential effectiveness of the many pedagogical approaches labeled open. In this article, rather than attempting to argue for a canonical definition of open pedagogy, we propose a new term, “OER-enabled pedagogy,” defined as the set of teaching and learning practices that are only possible or practical in the context of the 5R permissions that are characteristic of OER. We propose criteria used to evaluate whether a form of teaching constitutes OER-enabled pedagogy and analyze several examples of OER-enabled pedagogy with these criteria.

Keywords: OER-enabled pedagogy, open pedagogy, open learning, open educational practices

Introduction

The term "open pedagogy" has a long history and has been used in many contexts. For example, Elliot (1973) describes a tension between "closed" and "open" pedagogies with the former tending to be more focused on didactic discussion and the latter being connected with leading less formal discussions and students co-creating the context of the class. Mai (1978) discusses open pedagogy in the context of creating an "informal classroom where children might be trusted to learn by exploring according to their own interests, instead of being bored, demeaned, and alienated" (p. 231). Dufeu (1992) argues that open pedagogy is a philosophy in which the content of the course, as well as its progression, is determined by the needs and preferences of participants. Daniel (2004) refers to open pedagogy as one "that treats the student as an intellectual equal" (p. 9).

The association of "open pedagogy" with student-centered approaches has been strengthened in recent years concurrent with the development of new technologies. Hodgkinson-Williams and Gray (2009) use the term to refer to "the opening up of educational processes...enabled by Web 2.0 technologies" and argue that open pedagogy will play a more transformational role than open content (p.101). An Athabasca University white paper written in 2011 associates open pedagogy with learning digital literacies and teaching that is centered on the pedagogy of discovery (Day, Ker, Mackintosh, McGreal, Stacey, & Taylor, 2011). Hegarty (2015) defines open pedagogy as a broad range of attributes from participatory technologies to innovation and creativity.

In addition, "open pedagogy" has become closely associated with the creation, use, and sharing of open educational resources (OER). Weller (2013) states that open pedagogy "makes use of...abundant, open content (such as open educational resources, videos, podcasts), but also places an emphasis on the network and the learner's connections within it" (p. 10). Wiley (2013) similarly emphasized the link between OER and open pedagogy. Other authors have preferred the related term "open educational practices," which Cronin (2017) defines as "a broad descriptor of practices that include the creation, use, and reuse of open educational resources (OER) as well as open pedagogies and open sharing of teaching practices" (p. 16). The Open Educational Quality Initiative (OPAL; 2011) define open educational practices as "a set of activities around instructional design and implementation of events and processes intended to support learning. They also include the creation, use and repurposing of Open Educational Resources (OER) and their adaptation to the contextual setting. They are documented in a portable format and made openly available" (p. 13). Adding to the complexity, some people treat the term "open educational practices" as being synonymous with "open pedagogy," while others hold them to be distinct from each other.

The connection between open educational resources and open pedagogy marks a significant departure from the way the term was used in the 20th and early 21st centuries. The "open" in open educational resources indicates that these materials are licensed with copyright licenses that provide permission for everyone to participate in the 5R activities - retain, reuse, revise, remix, and redistribute. Wiley (n.d.) describes the 5Rs in more detail:

- **Retain -** the right to make, own, and control copies of the content (e.g., download, duplicate, store, and manage).

- **Reuse -** the right to use the content in a wide range of ways (e.g., in a class, in a study group, on a website, in a video).

- **Revise -** the right to adapt, adjust, modify, or alter the content itself (e.g., translate the content into another language).

- **Remix -** the right to combine the original or revised content with other material to create something new (e.g., incorporate the content into a mashup).

- **Redistribute -** the right to share copies of the original content, your revisions, or your remixes with others (e.g., give a copy of the content to a friend).

For several years, advocates, practitioners, and researchers in the open education movement have worked to prevent the weakening of the term "open" by calling out examples of "openwashing" - attempts by people and organizations to apply the label "open" to contexts in which copyright restrictions prohibit teachers and learners from engaging in the 5R activities (Weller, 2013; Pomerantz & Peek, 2016). Those interested in OER care about the way the word "open" is used in educational contexts.

The wide range of variation in the many recent definitions of open pedagogy makes it increasingly difficult to make sense of the term, potentially leading to claims of openwashing and creating other practical problems in the context of teaching and learning practices. From a research perspective, the dearth of agreement on a common definition makes evaluating the impacts of open pedagogy on student learning, student engagement, and other metrics of interest essentially impossible since we cannot specify what we are evaluating. In making this claim, we do not mean to cast doubt on the potential effectiveness of the many pedagogical approaches labeled open. Indeed, many of these pedagogies are inspiring, have the appearance of effectiveness, and seem worthy of replication. However, in order to move research in the field forward, there is a need for clarity.

Rather than attempting to propose a single, canonical definition of open pedagogy, we propose a new term, "OER-enabled pedagogy." We define OER-enabled pedagogy as the set of teaching and learning practices that are only possible or practical in the context of the 5R permissions which are characteristic of OER. Pedagogy is not generally described in terms of copyright, so we pause here to explain the relationship between permission to engage in the 5R activities and teaching and learning practices.

We accept as axiomatic that students learn by doing. The function of copyright is to prohibit people from engaging in broad categories of activity (e.g., making copies or creating derivative works) without permission from a rights holder. If students learn by doing, and copyright makes it illegal to engage in certain kinds of doing without a license, then copyright necessarily functions to limit the ways in which students can learn. The permissions to engage in the 5R activities that are granted in association with OER lift these restrictions. Consequently, when using OER, as opposed to traditionally copyrighted resources, students are free to engage in a broader range of activities and, therefore, to learn in a broader range of ways. The core ideas of OER-enabled pedagogy are in many ways a combination of openness as characterized by the 5Rs and Papert's (1991) notion of constructionism. Papert writes that the simplest definition of constructionism is “learning-by-making,” and relates the following story of how he arrived at the idea:

> More than 20 years ago, I was working on a project at the Muzzey Junior High School in Lexington, MA, which had been persuaded by Wally Feuerzeig to allow a seventh grade to "do Logo" instead of math for that year. This was a brave decision for a principal who could not have known that the students would actually advance their math achievement score, even though they didn't do anything that resembled normal school math that year! But the story I really want to tell is not about test scores. It is not even about the math/Logo class. It is about the art room I used to pass on the way. For a while, I dropped in periodically to watch students working on soap sculptures and mused about ways in which this was not like a math class. In the math class students are generally given little problems which they solve or don't solve pretty well on the fly. In this particular art class they were all carving soap, but what each student carved came from wherever fancy is bred and the project was not done and dropped but continued for many weeks. It allowed time to think, to dream, to gaze, to get a new idea and try it and drop it or persist, time to talk, to see other people's work and their reaction to yours--not unlike mathematics as it is for the mathematician, but quite unlike math as it is in junior high school. I remember craving some of the students' work and learning that their art teacher and their families had first choice. I was struck by an incongruous image of the teacher in a regular math class pining to own the products of his students' work! An ambition was born: I want junior high school math class to be like that. I didn't know exactly what "that" meant but I knew I wanted it. I didn't even know what to call the idea. For a long time it existed in my head as "soap-sculpture math.” (para. 8)

In soap-sculpture math, Papert (1991) saw that learning “happens especially felicitously in a context where the learner is consciously engaged in constructing a public entity” (para. 2) - something that others can see, review, critique, and value. In introducing the idea of OER-enabled pedagogy, we ask what it means to add the 5R permissions to these public entities - to be consciously engaged in either building upon work previously done by another or to construct a new public entity that explicitly offers other learners permission to publicly transform and adapt it. When student works are openly licensed, granting others 5R permissions in their use of the artifacts, each work becomes the beginning of an ongoing conversation in which other learners participate as they contextualize and extend the work in support of their own learning. Open licensing also ensures that these artifacts will be perpetually and freely available to all who wish to engage them as part of their learning. Rather than a single assignment that is completed, displayed, and archived (or recycled), the artifacts constructed in the context of open become a source of renewal and additional learning-by-making for later learners.

One concrete example of combining constructionism and openness into OER-enabled pedagogy is Wiley’s (2013) notion of “renewable assignments,” which he contrasts with “disposable assignments.” Disposable assignments are those assignments that both faculty and students understand will ultimately be thrown away. Essays are examples of assignments that frequently fit into this category - students write the essays, faculty grade and provide feedback on the essays and return them to students, and students do or do not look through faculty comments and then throw the paper in the recycle bin (or delete it). In discussing disposable assignments, Wiley does not imply that these kinds of assignments cannot result in powerful student learning for that student in that context. He only calls our attention to the fact that millions of hours of work are done, graded, and thrown away each year. We echo this concern over what seems to be a missed opportunity. In contrast to disposable assignments, Wiley introduces the idea of renewable assignments - assignments which both support an individual student's learning and result in new or improved open educational resources that provide a lasting benefit to the broader community of learners.

We might consider a continuum of criteria that distinguish disposable assignments from renewable assignments, as indicated in Table 1.

Table 1

Criteria Distinguishing Different Kinds of Assignments

	Student creates an artifact	The artifact has value beyond supporting its creator's learning	The artifact is made public	The artifact is openly licensed
Disposable assignments	X			
Authentic assignments	X	X		
Constructionist assignments	X	X	X	
Renewable assignments	X	X	X	X

Thus, in determining whether a particular approach should be labeled OER-enabled pedagogy, it matters whether openly licensed resources are a vital part of the practice. We propose the following four-part test to determine the extent to which a specific teaching and learning practice qualifies as OER-enabled pedagogy, as exemplified by the idea of renewable assignments:

1. Are students asked to create new artifacts (essays, poems, videos, songs, etc.) or revise / remix existing OER?
2. Does the new artifact have value beyond supporting the learning of its author?
3. Are students invited to publicly share their new artifacts or revised / remixed OER?
4. Are students invited to openly license their new artifacts or revised / remixed OER?

In the remainder of the paper we provide several examples of OER-enabled pedagogy and analyze these examples using the four-part test listed above. We then close by providing suggestions for how future research on OER-enabled pedagogy might be conducted.

Examples of OER-Enabled Pedagogy

Here we provide several examples of types of OER-enabled pedagogies. This set of categories is meant to be illustrative and not comprehensive.

OER-enabled pedagogies resulting in the creation of supplementary learning resources designed to facilitate the learning of other students. OER-enabled pedagogies can result in the creation of supplementary learning resources designed to improve the understanding of future students. Wiley, Webb, Weston, and Tonks (2017) describe how student-created OER in a secondary (middle and high school) setting helped improve student learning. The context for this study was a Digital Photography course at Mountain Heights Academy. Each semester that the course has been taught since its introduction in 2011, students were given the option to release their own photos with a Creative Commons license. The openly licensed photos were evaluated by the instructor and the best examples of each particular concept were selected to be integrated into the course and used by students in subsequent semesters.

Students were also offered extra credit to create tutorial videos, chapter summaries, and review games for a particular topic; these tutorial resources were also evaluated by the teacher and some were selected to be integrated into the course. Students who demonstrated high levels of mastery in the course were then offered the opportunity to be a teaching assistant for the upcoming semester. These students created additional materials, including guided notes for each unit that provide deeper explanations of concepts, study guides for exams, tutorial videos that provide scaffolding and support to learners who benefit from having the material presented from a different perspective or in a different medium, and review presentations and games that can assist students to learn in a variety of ways. These ancillary materials are all licensed as OER and added to the course after review by the teacher. The results of the study reported by Wiley et al. (2017) were that the average grade on student assignments rose significantly as more student-created OER were added to the course.

To examine the extent to which this approach qualifies as OER-enabled pedagogy, we apply the four-part test listed above:

1. **Are students asked to create new artifacts (essays, poems, videos, songs, etc.) or revise / remix existing OER?**

   Yes. New artifacts were created.

2. **Does the new artifact have value beyond supporting the learning of its author?**

   Yes. The artifacts were meant to also support the learning of other students.

3. **Are students invited to publicly share their new artifacts or revised / remixed OER?**

   Yes, students were invited to publicly share their creations, which are available online.

4. Are students invited to openly license their new artifacts or revised / remixed OER?

Yes.

Based on the answers to these questions, this approach clearly qualifies as OER-enabled pedagogy.

A second example from this genre comes from Jhangiani (2017), who also describes using OER-enabled pedagogy to facilitate the learning of current students while potentially improving the learning of future students. Over the course of a semester, he asked students taking a Social Psychology class to create test questions based on the material they were learning. Jhangiani felt that having his students write well-crafted questions (including plausible distractors) would help them attain a deeper level of understanding; moreover, it would help create a test bank for the open textbook that was being used in the course (and did not have an associated test bank). Jhangiani's class of 35 students wrote 1,400 questions throughout the semester. While Jhangiani did not consider the resulting test bank to be sufficiently polished to be used by other instructors, it provides a base that can be modified and improved on by future students.

Again, to examine the extent to which this approach qualifies as OER-enabled pedagogy, let us apply the four-part test listed above:

1. Are students asked to create new artifacts (essays, poems, videos, songs, etc.) or revise / remix existing OER?

Yes. New artifacts were created based on existing OER, namely a test bank.

2. Does the new artifact have value beyond supporting the learning of its author?

Yes. The questions provide formative, self-check opportunities for other students in the class and, perhaps eventually, other students.

3. Are students invited to publicly share their new artifacts or revised / remixed OER?

Not yet. The questions were available to class members but deemed not yet ready for public consumption.

4. Are students invited to openly license their new artifacts or revised / remixed OER?

Jhangiani does not report on this.

Because students were adding value to a pre-existing OER, if we assume that their resulting work was openly licensed, this approach would qualify as OER-enabled pedagogy.

OER-enabled pedagogy and worked examples. In his meta-meta-analysis of a range of educational practices, Hattie (2009) identified worked examples as an educational intervention associated with strong improvements in student learning. Worked examples provide students with step-by-step templates of how to complete tasks or solve problems and are particularly prevalent in math. Figure 1 provides an example of a worked example of a trigonometry problem (Ctcleung, 2014).

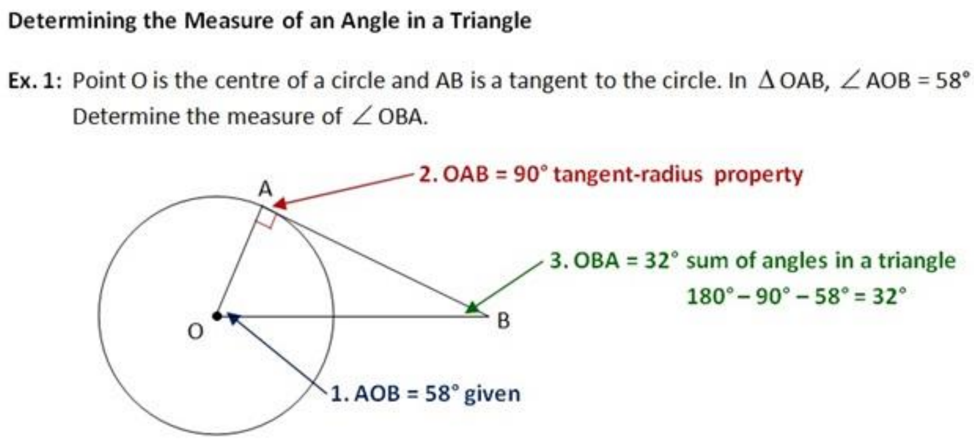

Figure 1. A sample worked example.

Through an OER-enabled pedagogy approach, students might create or modify openly licensed worked examples, specifically in topics that have proven troublesome to students in past semesters. This approach benefits students who create the worked examples, as creating the worked problems expands and deepens their knowledge. Moreover, it is beneficial for future students who can use these worked examples to help them process difficult topics in future semesters. In evaluating this approach, we find the following answers to the four-part test described above:

1. **Are students asked to create new artifacts (essays, poems, videos, songs, etc.) or revise / remix existing OER?**

   Yes. These worked examples could be independent of pre-existing resources, or be built to align with OER, or could include revisions and remixes of existing worked examples.

2. **Does the new artifact have value beyond supporting the learning of its author?**

   Yes. Worked examples can support the learning of future students.

3. **Are students invited to publicly share their new artifacts or revised / remixed OER?**

   Yes, these works could be posted online.

4. **Are students invited to openly license their new artifacts or revised / remixed OER?**

   Yes. Doing so would allow for the worked examples to be used in other contexts.

Because students would be creating new learning material (possibly connected with pre-existing OER), the first criterion is met. If we assume that their resulting work is openly licensed and publicly available, then this technique would be OER-enabled pedagogy.

OER-enabled pedagogy and student summaries. Another way that students could generate resources that would both demonstrate their learning and help future generations of learners is to create summaries of key concepts related to a course. For example, in an English course in which students are studying *A Tale of Two Cities*, students could produce written or video-based presentations that summarize key historical context or important aspects of the storyline. Such summaries could include identifying symbolism or making connections between events of the book and contemporary society. These summaries could be both used and improved upon by future generations of learners. The answers to the four-part test for this approach are the same as the previous example.

OER-enabled pedagogy and new contexts. One challenge all learners face is the transferring knowledge from one context to another. For example, a student may know that the earth revolves around the sun, but may struggle to understand whether this rotation influences the appearance of the moon in the night sky. Students could be assigned to take a principle or concept taught in class and concretely explain it in another context. Such an approach would benefit both current and future learners. The answers to the four-part test for this approach are the same as the previous example.

OER-enabled pedagogy that results in primary course resources such as textbooks. Another broad category of OER-enabled pedagogy approaches concern the creation or revision/remixing of learning resources. For example, Robin DeRosa of Plymouth State University became concerned about the high cost of the textbook in the course she was teaching (DeRosa, 2016). In this American literature class, the majority of the texts that comprised her textbook were in the public domain, which made it seem incongruent to require students to purchase a textbook that cost nearly $100.00.

Working with students she hired, DeRosa (2016) set about creating a basic open access anthology for her students. However, her students were somewhat dismayed at the lack of contextual introductions to each text in the anthology, as introductions are typically included in traditional textbooks and provide important background information. As part of the course, students created these introductions throughout the class, generally submitting them prior to the text being covered in class, and often revised after class. Student made other helpful edits to the anthology, such as modernizing spelling and creating videos, discussion questions, and other assignments that were related to the primary texts.

In evaluating this potential approach using the four-part test, we find the following:

1. **Are students asked to create new artifacts (essays, poems, videos, songs, etc.) or revise / remix existing OER?**

   Yes. Students were involved in both collating, organizing and creating OER.

2. **Does the new artifact have value beyond supporting the learning of its author?**

Yes. The anthology will be of value to future students and other interested in the topic.

3. Are students invited to publicly share their new artifacts or revised / remixed OER?

Yes.

4. Are students invited to openly license their new artifacts or revised / remixed OER?

Yes, they were integrated into the learning materials.

This example is a clear (and some would say classic) example of OER-enabled pedagogy.

Another example of this general category is the textbook *Project Management for Instructional Designers* (described in Randall, Johnson, West, & Wiley, 2013). This book came about when David Wiley was teaching a course on this topic and found that there was no suitable textbook available. However, there was a pre-existing, openly licensed textbook on project management that Wiley was able to collaboratively revise with his students (as part of their coursework) to create a version specifically for instructional designers. They did so by adding examples relevant to educational technology, integrating new video case studies they produced, and making other changes that further improved the book for educational technology students. Students in future iterations of the course made further revisions and remixes. An analysis of this example is similar to the previous one.

OER-enabled pedagogy and Wikipedia. Another category of OER-enabled pedagogy is connected with Wikipedia. The basic idea behind many of these approaches is that a major assignment that students complete is writing or rewriting Wikipedia articles. One classic example of this type of pedagogy comes from a class titled "Murder, Madness & Mayhem." Beasley-Murray (n.d.) was teaching a course at the University of British Columbia that focused on Latin American literary texts. He assigned students to edit (and if necessary create) Wikipedia articles about each of the texts covered in class. Beasley-Murray felt that this project would be important because it had "tangible and public, if not necessarily permanent, effects" (para. 9) in contrast with a final essay or exam which would be "written in haste; for one particular reader, the professor; and thereafter discarded" (para. 9). Another advantage of this assignment was that it motivated students to "re-read and reflect upon their own work" (para. 10). As Wikipedia requires sources for its entries, students were pushed to make sure that they were properly using prior research. Moreover, there were many people (besides the professor) reading their work and ensuring accuracy. Ultimately, 12 articles were created as part of this class; three of them achieved "featured article" status and eight achieved "good article" status (at the time, fewer than .5% of Wikipedia articles achieved either of these statuses).

Other examples of this type of OER-enabled pedagogy are plentiful. Azzam et al. (2016) taught classes to fourth year medical students over a two-year period in which editing Wikipedia articles related to medicine was the primary purpose of the class. In this class, 43 students made a total of 1,528 edits and added 274 references (and deleted several lower-quality references). These 43 articles were viewed over one million times, indicating a significant contribution to society. In examining these Wikipedia-related examples using the four-part test described above, we find the following:

1. **Are students asked to create new artifacts (essays, poems, videos, songs, etc.) or revise / remix existing OER?**

   Yes. The nature of the assignment is the creation or modification of OER.

2. **Does the new artifact have value beyond supporting the learning of its author?**

   Yes. Wikipedia articles are viewed by millions of people each month.

3. **Are students invited to publicly share their new artifacts or revised / remixed OER?**

   Yes. By definition, Wikipedia articles are publicly shared.

4. **Are students invited to openly license their new artifacts or revised / remixed OER?**

   Yes. By definition, Wikipedia articles are openly licensed.

This is an excellent example of OER-enabled pedagogy - it would not have been possible or practical if the only available encyclopedias were copyrighted.

Further Research Needed

Several years ago, Ehlers (2011) identified a need for research to determine the efficacy of OER. At that time some believed that, because OER are free of cost, they are necessarily inferior to commercial alternatives and that students who use OER would learn less. Conversely, some argued that open textbooks would dramatically improve student learning as students gained greater access to learning resources. Six years later, there have been more than a dozen studies, most of which have found OER to have a small positive impact on learning (Hilton, 2016). Will widespread adoption of OER-enabled pedagogy spark dramatic improvements in learning? We need more use of renewable assignments and other OER-enabled pedagogies, as well as more research, to answer this question. For example, a study might examine the question how much additional benefit is gained from the various criteria associated with OER-enabled pedagogy? For example, consider the following questions:

- Do students assigned to create, revise, or remix artifacts find these assignments more valuable, interesting, motivating, or rewarding than other forms of assessment? Why or why not?
- Do students who make their assignments publicly available demonstrate greater mastery of learning outcomes or show more enthusiasm for their work than students assigned traditional assessments? Why or why not?

- Do students who openly license their work find additional learning benefits? Does openly licensed student work produce additional benefits to the broader community?

- Are there any drawbacks (real or perceived) that are voiced by students or faculty that participate in OER-enabled pedagogy?

Those who study these questions need to carefully consider the metrics they use when determining whether OER-enabled pedagogy leads to increased learning outcomes. In what ways would we expect OER-enabled pedagogy to make a difference in student learning? Much of the OER efficacy research done to date focuses on GPA, pass rates, and other traditional metrics. These might be appropriate for measuring the influence of adopting OER-enabled pedagogy; however, there may be better metrics. For example, OER-enabled pedagogy could conceivably lead to changes in student creativity, enthusiasm, satisfaction, and other outcomes sometimes labeled "deeper learning." Pre-existing and new instruments could be used to measure gains or losses in these areas.

Conclusion

In the early days of OER adoption, research found that there are ways of adopting OER that actually cost more than using commercial materials. For example, Wiley, Hilton, Ellington, and Hall (2012) illustrate how a poorly planned print-on-demand strategy can make OER more expensive than publisher textbooks. Just as researchers spent time in the early years of OER adoption research specifically investigating the whether-or-nots and hows of cost savings, we need to spend time in these early years of researching OER-enabled pedagogy specifically investigating the value students and faculty find in doing this work, how motivating or engaging they find it, and how it can be improved.

Students are the authors and copyright holders of the homework and other artifacts they create as part of their education. There is no morally or ethically appropriate scenario in which faculty can *require* students to openly license their homework or other creations as part of an assignment. Caution is especially important when working with students who are minors. However, faculty can espouse the benefits of openness and appropriately advocate for students to license their works under a Creative Commons license. This advocacy will be more effective if the faculty member is using OER in the class and can point to OER they have created and shared.

Powerful examples of OER-enabled pedagogy will give faculty specific and direct reasons to adopt OER. As faculty come to understand that OER allows for the benefits of open pedagogy, the adoption of OER will significantly accelerate. This accelerated adoption of OER will, in turn, significantly increase the quality (through OER-enabled pedagogy) and affordability (through cost savings) of education for learners everywhere.

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Efficacy - Workshop Day 2

Introduction

The readings for the second day of the workshop are a 2019 article by Virginia Clinton and Shafiq Khan and a 2019 article by Johnny B. Allred and Cheryl Ann Murphy. The two articles are grounded in experimental and empirical research on the effectiveness of electronic textbooks. They are intended to complement the more theoretical and philosophical articles in the openability section by putting to test the essential claim or hypothesis that the adoption of open textbooks by instructors will benefit student learning.

Clinton, V., & Khan, S. (2019). Efficacy of open textbook adoption on learning performance and course withdrawal rates: A meta-analysis. *Aera Open 5*(3), 1-20. https://doi.org/10.1177/2332858419872212

This is the most recent (as of this writing) of several meta-analyses of the efficacy of open textbooks. A *meta-analysis* generates statistics from the combined results of multiple research studies on a given topic and then uses these statistics to draw conclusions and make recommendations. We chose to include a meta-analysis because it is a convenient way to obtain a birds-eye view of research conducted on the effectiveness of open textbooks. Unless you have a background and interest in statistics, feel free to skim or ignore the authors' documentation of their statistical procedures and programming code.

As you read the article, please

1. Reflect on the implications of the authors' findings and recommendations and note any gaps in the data and/or oversights in their interpretation of the data
2. Consider how you might structure a future study of the efficacy or perception of open textbooks and/or OER in a course taught by you and/or others at your institution
3. Add at least one discussion question to our class Google doc

Allred, J. B., & Murphy, C. A. (2019). Interactive electronic textbook use in higher education: grades, engagement, and student perceptions. *International Journal of Innovation and Learning, 25*(3), 296-309. https://doi.org/10.1504/IJIL.2019.098895

Whereas Clinton and Kahn (2019) measure the impact of openness and do not assume any functional or practical differences between open and commercial textbooks, Allred & Murphy (2019) measures the impact of interactivity in the case of a single commercial electronic textbook with interactive features that would not be feasible in a print textbook.

As you read this study, please

1. Reflect on what beneficial affordances an electronic textbook might offer aside from the potential of being freely or openly available
2. Add at least one discussion question to our class Google doc

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Efficacy of Open Textbook Adoption on Learning Performance and Course Withdrawal Rates: A Meta-Analysis

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*Open textbooks have been developed in response to rising commercial textbook costs and copyright constraints. Numerous studies have been conducted to examine open textbooks with varied findings. The purpose of this study is to meta-analyze the findings of studies of postsecondary students comparing learning performance and course withdrawal rates between open and commercial textbooks. Based on a systematic search of research findings, there were no differences in learning efficacy between open textbooks and commercial textbooks (*k *= 22,* g *= 0.01,* p *= .87,* N *= 100,012). However, the withdrawal rate for postsecondary courses with open textbooks was significantly lower than that for commercial textbooks (*k *= 11,* OR *(odds ratio) = 0.71,* p *= .005,* N *= 78,593). No significant moderators were identified. Limitations and future directions for research, such as a need for more work in K–12 education, outside of North America, and that better examine student characteristics, are discussed.*

Keywords: *open textbooks, course withdrawal, open educational resources, meta-analysis*

Textbooks are useful and ubiquitous teaching and learning resources in education (Behnke, 2018). Commercial textbooks have been frequently criticized for their high prices, which have increased substantially in the past few decades (Blomgren, 2018; Perry, 2015). These prices contribute to the financial cost of education that is shouldered by taxpayers and students. As an alternative to commercial textbooks, open textbooks, which are electronically accessible without charging the user, have been developed (Smith, 2009). Many studies have examined differences in learning performance as well as course withdrawal rates between open and commercial textbooks (see Hilton, 2016, 2018, for reviews). However, results have been mixed with some showing positive results (Colvard, Watson, & Park, 2018; Hilton, Fischer, Wiley, & Williams, 2016), some showing negative results (e.g., Gurung, 2017), and some showing no difference between commercial and open textbooks (Allen et al., 2015; Grissett & Huffman, 2019; Medley-Rath, 2018). The purpose of this article is to meta-analyze the research findings comparing learning performance and course withdrawal rates between open and commercial textbooks. The findings from this meta-analysis may be used to inform instructors and institutions with their choice of textbooks.

Literature Review

The development of open textbooks is part of a broader movement in open educational resources (OER). OER is an umbrella term for a variety of learning materials, including textbooks, videos, online modules, music, brief readings, and music (Butcher, 2015). According to the William and Flora Hewlett Foundation (2019), which has supported OER for decades, OER are

> teaching, learning, and research resources that reside in the public domain or have been released under an intellectual property license that permits their free use and re-purposing by others. (para. 7)

Textbooks were the focus of this manuscript for three reasons. One is that textbooks are commonly used learning resources throughout postsecondary education (Illowsky, Hilton, Whiting, & Ackerman, 2016). Another reason is that open textbooks are a type of OER that has a notable body of research on its efficacy (Weller, de los Arcos, Farrow, Pitt, & McAndrew, 2015). Finally, by focusing the analyses on a single type of OER (in this case, textbooks), the comparisons between OER and commercial resources are clearer.

A survey of postsecondary faculty found that many faculty express frustrations with the high costs of commercial materials, and a majority of faculty agreed that the high cost of commercial materials was a problem (Seaman & Seaman, 2018). However, the same survey indicated that one of the major concerns that faculty have about adopting open textbooks is whether their quality is comparable with commercial textbooks (Seaman & Seaman, 2018). Concerns about quality have been noted as a barrier to open textbook adoption in other surveys of faculty as well (Belikov & Bodily, 2016; Jhangiani, Pitt, Hendricks, Key, & Lalonde, 2016).

These concerns are not unwarranted. Indeed, in two studies comparing performance on researcher-developed, objective learning measures, students enrolled in courses with commercial textbooks outperformed students enrolled in courses with open textbooks (Gurung, 2017). However, there have been numerous studies on open textbooks indicating no meaningful differences in learning compared with commercial textbooks (e.g., Clinton, 2018; Engler & Shedlosky-Shoemaker, 2019; Jhangiani, Dastur, Le Grand, & Penner, 2018; Medley-Rath, 2018) that need to be considered alongside Gurung's (2017) findings. For this reason, a meta-analysis in which the overall efficacy of open textbooks across studies were summarized would be informative for instructors, administrators, and policymakers.

There are reasons to expect that students in courses with open textbooks would outperform those in courses with commercial textbooks. According to the *access hypothesis*, many students do not purchase the textbook because of the cost (Grimaldi, Basu Mallick, Waters, & Baraniuk, 2019). Therefore, the use of an open-source textbook would allow more students to have access to the textbook, which would logically improve student performance on learning measures dependent on textbook access (e.g., quiz performance on required readings). In addition, having access to a textbook also provides students with a resource to help them better understand the content covered in class. Following this hypothesis, students should do better in courses with open textbooks than commercial textbooks.

Examinations of studies on open textbook efficacy have been the topic of two systematic reviews (Hilton, 2016, 2018) as well as nonsystematic, narrative reviews (Clinton, 2019a; Wiley, Bliss, & McEwen, 2014). In these reviews, the overall conclusions based on qualitative analyses were that OER, including open textbooks, were as effective for student learning as commercial materials. These reviews provide thoughtful, in-depth thematic analyses of the research on the topic. However, there are no published meta-analyses on this topic, to our knowledge, and conducting meta-analyses would build on these reviews by combining the effects of multiple studies to get overall quantitative effect sizes.

Given that random assignment is generally not feasible for comparing textbooks, nearly all of the research has involved quasi-experiments with varying levels of quality in terms of controlling for confounders, such as comparing courses taught by different instructors. These methodological limitations constitute a significant limitation in research on the efficacy of open textbooks (see Griggs & Jackson, 2017; Gurung, 2017, for discussions). A meta-analysis could examine some of the potential effects of these confounders by including moderator analyses based on study quality variables. The use of the same instructor in courses with open textbooks compared with commercial textbooks is important given the variability in grading practices and pedagogical quality across individual instructors (de Vlieger, Jacob, & Stange, 2017). Another confounder to consider is whether student prior achievement or knowledge varied when comparing courses. This is important to consider given that prior academic performance is a clear predictor of future performance on learning measures (Cassidy, 2015). Furthermore, in one study, a course with an open textbook had higher average grades than the same course with the same instructor using a commercial textbook, but the students in the course with the open textbook had stronger academic backgrounds based on high school grade point averages (Clinton, 2018). In addition, many studies used different instruments to measure learning (e.g., different exams and quizzes that contributed to final grades). The use of different instruments is a clear confounder when comparing learning efficacy from open and commercial textbooks as different instruments would likely yield different scores due to measurement error.

The availability of an open textbook could potentially influence postsecondary students' decisions on whether to complete a course or withdraw from it. One reason postsecondary students state for withdrawing from a course is that they cannot afford the textbook (Michalski, 2014). Indeed, approximately 20% of postsecondary students report that the expense of a textbook motivated their decision to withdraw from a course (Florida Virtual Campus, 2016). These course withdrawals lead to losses of time and tuition for students and increase the amount of time it takes to complete a degree, making the overall cost of a postsecondary education higher (Boldt, Kassis, & Smith, 2017; Nicholls & Gaede, 2014). Students have indicated that having an open textbook for the course was a reason they completed that course (Hardin et al., 2019). It is possible that postsecondary students who are behind in a course may be more likely to complete the course if there is an open-access textbook they can use to access the material rather than spend hundreds of dollars for a commercial textbook. This could potentially lead to courses with open textbooks having lower withdrawal rates than courses with commercial textbooks. However, it should be noted that postsecondary students withdraw from courses for a multitude of reasons that are unrelated to finances, such as stressors in their personal lives or dislike of the instructor (Hall, Smith, Boeckman, Ramachandran, & Jasin, 2003; Michalski, 2014).

Research Questions

Three research questions guided this meta-analytic research:

Research Question 1: What is the efficacy of open textbooks compared with commercial textbooks in terms of student learning?

Research Question 2: What are the differences in withdrawal rates for courses with open textbooks compared with commercial textbooks?

Research Question 3: Do differences in confounders in the methodology moderate the results for Research Questions 1 and 2?

Method

A search and analysis plan for this meta-analysis was preregistered prior to beginning this project (Clinton, 2019b).

Inclusion Criteria

In order to be included in this meta-analysis, the report needed to meet certain criteria. First, the report needed to have findings comparing student learning performance and/or withdrawal rates between open and commercial textbooks. It needed to report sufficient information to be used in the meta-analysis (e.g., means and standard deviations, *t* tests, withdrawal rate, number of students for each textbook type), or the authors provided the necessary information on request (e.g., Grewe & Davis, 2017; Lawrence & Lester, 2018). The report needed to be in English. Postsecondary students needed to be the participants because they are expected to purchase their course materials and are more directly affected by cost. There were no restrictions regarding the type of dissemination (e.g., journal articles, dissertations, conference presentations), and unpublished findings that were available to the authors of this meta-analysis were eligible.

Search Procedure

A systematic search for studies comparing learning measures and/or withdrawal rates between students using open and commercial textbooks was conducted in multiple steps. First, scholarly dissemination was searched for in the following databases: Scopus, DOAJ (Directory of Open Access Journals), ProQuest, PSYCinfo, and ERIC using the search terms *open source textbook** and *OER* AND *textbook* were conducted in August of 2018 (see Appendix A for search terms used). This yielded 578 citations, of which 117 duplicates were removed. The titles and abstracts of these 461 citations were screened by the first author, and 97 were determined to be relevant (the internet-based tool Abstrackr was used for screening; Wallace, Small, Brodley, Lau, & Trikalinos, 2012). The full texts of the remaining 97 reports were examined. Based on examinations of the full texts, 20 reports were determined to be relevant (however, further on in analyses, three reports from this list had to be removed because the necessary statistics were not available, but there were backward and forward searches of citations for these reports as described in the following paragraph).

A list of these relevant reports found at this stage was compiled and sent to the Community College Consortium for Open Educational Resources–Advisory listserv, the authors of these reports were emailed, and a tweet was posted on this manuscript's first author's Twitter page with the hashtags #oer and #opensource requesting any additional reports or unpublished data (this yielded one additional report). The research reports posted on "The Review Project" of the Open Education Group's website (https://openedgroup.org/) were also examined, which yielded one more report. After these relevant reports were identified, a backward search of the reference lists of these reports was conducted (no new reports were identified in this way). Then, a forward search of the citations of the relevant reports in Google Scholar was conducted, which identified one more report. The titles and abstracts of all presentations at Open Education 2018 were examined, which led to the identification of one more report. The systematic reviews of OER conducted by Hilton (2016, 2018) were examined, but no additional relevant studies were found. This led to a total of 22 reports with 23 independent studies (Gurung, 2017, reported two independent studies). This process ceased in October 2018. Twenty-two of these studies were analyzed in the learning efficacy meta-analysis (Table 1). Eleven of these studies were analyzed in the course withdrawal meta-analysis (Table 2).

Coding of Studies

To provide descriptive information, assess study quality, and obtain information for moderator analyses, the studies were coded using the criteria found in Appendix B. Items pertaining to study quality were based on the Study Design and Implementation Assessment Device (Valentine & Cooper, 2008). The Study Design and Implementation Assessment Device provides researchers with questions to study quality regarding construct, internal, external, and statistical conclusion validity. The studies were coded and double-coded by the first author. In addition, research assistants coded 25% of the reviews (interrater reliability was good, $\kappa = 0.78$; see Follmer, 2018, for a similar approach). The first author resolved disagreements.

Statistical Procedures

To summarize the findings across learning measures, Hedges's *g* was used. Hedges's *g* is a standardized mean difference metric that is bias-corrected based on sample sizes (Enzmann, 2015; Hedges, 1981). To calculate Hedges's *g* for each learning measure, either descriptive statistics (e.g., means and standard deviations, number of students passing a course) or inferential statistics (e.g., *t* tests) in addition to sample sizes entered into Comprehensive Meta-Analysis software (Version 3; Biostat, Englewood, NJ; note that some effect sizes based on dichotomous dependent variables were converted from the odds ratio to standardized mean differences following Polanin and Snilstveit, 2016). Corresponding authors contacted with requests for any missing statistical information that was necessary. If the relevant statistics could not be obtained, the study was not included (as shown in Figure 1, this was the case for one full text report). A positive Hedges's *g* indicates that the mean values for open textbooks were greater than those for commercial textbooks.

TABLE 1
Descriptions of Studies for Learning Performance Meta-Analysis

Author/s (Year)	Sample Size (Open and Commercial)	Learning Measure	Content Area(s)	Institution Type (Country)	Limitations
Allen et al. (2015)	Open = 377. commercial = 348	Normalized learning gain on standardized assessment of chemistry knowledge	Hard science	4-year public university (United States)	There were substantial changes to the course beyond adopting an open-source textbook
Basu Mallick, Grimaldi, Whittle, Waters, and Baraniuk (2018)	Open = 4,247, commercial = 14,474	Course grades	Humanities	2-year community college (United States)	There were differences in prior academic achievement that could not be controlled for in the analyses
Chiorescu (2017)	Open = 159, commercial = 447	Course grades (C or better)	Math	4-year public college (United States)	No assessment of prior knowledge or achievement
Choi and Carpenter (2017)	Open = 175, commercial = 114	Course grades	Social science	4-year public university (United States)	No inferential statistics reported
Clinton (2018)	Open = 204, commercial = 316	Course grades	Social science	4-year public university (United States)	There were differences in prior academic achievement that could not be controlled for in the analyses
Colvard et al. (2018)	Open = 10,141, commercial = 11,681	Course grades	Varied	4-year public university (United States)	No assessment of prior knowledge or achievement
Engler and Shedlosky-Shoemaker (2019)	Open =24, commercial = 25	Course exam performance	Social science	4-year private college (United States)	Small sample sizes
Feldstein et al. (2012)	Open = 1,394, commercial = 2,176	Course grade C or above	Business	4-year public university (United States)	No assessment of prior knowledge or achievement; different courses compared
Grewe and Davis (2017)	Open = 58, commercial = 60	Course grades	Humanities	2-year public college (United States)	Insufficient statistics reported to estimate effect size
Grissett and Huffman (2019)	Open = 31, commercial = 29	Course grades	Social science	4-year public university (United States)	Small sample sizes
Gurung (2017), Study 1	Open = 405, commercial = 398	Multiple-choice quiz	Social science	Multiple 4-year public colleges and universities (United States)	Open and commercial students from different populations; different instructors
Gurung (2017), Study 2	Open = 753, commercial = 584	Multiple-choice quiz	Social science	Multiple 2-year and 4-year public colleges and universities (United States)	Open and commercial students from different populations; different instructors

(continued)

TABLE 1 (CONTINUED)

Author/s (Year)	Sample Size (Open and Commercial)	Learning Measure	Content Area(s)	Institution Type (Country)	Limitations
Hardin et al. (2019)	Open = 1,014, commercial = 2,237	Exams	Social science	4-year public university (United States)	Different instructors taught courses with OER and commercial textbooks
Hendricks, Reinsberg, and Rieger (2017)	Open = 755, commercial = 1,492	Final exam	Hard science	4-year public university (Canada)	Limited inferential statistics reported; no analysis of possible differences in prior knowledge
Hilton, Gaudet, Clark, Robinson, and Wiley (2013)	Open = 2,043, commercial = 4,164	Course grade of C or better	Math	2-year community college (United States)	Confound of changes in course placement policies; inferential statistics not reported
Hilton et al. (2016)	Open = 2,014, commercial = 43,223	Course grade	Varied	2-year community college (United States)	Different instructors taught courses with OER and commercial textbooks
Jhangiani et al. (2018)	Open = 94, commercial = 83	Exams	Social science	4-year public university (Canada)	Different instructors taught courses with OER and commercial textbooks; summer terms were compared with academic year, may be a different population
Lawrence and Lester (2018)	Open = 178, commercial = 200	Course grades	Social science	4-year public university (United States)	Limited reporting of descriptive and inferential statistics for grades; no assessment of prior knowledge or achievement
Medley-Rath (2018)	Open = 23, commercial = 24	Improvement on posttest course grade	Social science	2-year community college (United States)	Online courses were mentioned, but not included in analyses; small sample sizes
Robinson (2015)	Open = 1,908, commercial = 1,908	Course grade	Varied	Multiple: 2-year community colleges, 4-year private college, and 4-year public college (United States)	Different instructors; no assessment of prior knowledge or achievement
Westermann Juárez and Venegas Muggli (2017)	Open = 31, commercial = 30	Course grades	Mathematics	Postsecondary, details N/A (Chile)	Small sample sizes
Winitzky-Stephens and Pickavance (2017)	Open = 329, commercial = 1,120	Course grades	Varied	2-year community college (United States)	Different courses compared; no assessment of prior knowledge or achievement

Note. OER = open educational resources; N/A = not applicable.

TABLE 2

Descriptions of Studies for Withdrawal Rate Meta-Analysis

Author/s (Year)	Sample Size (Open and Commercial)	Content Area(s)	Institution Type (Country)	Limitations
Chiorescu (2017)	Open =159, commercial = 447	Math	4-year public college (United States)	No assessment of prior knowledge or achievement
Clinton (2018)	Open = 232, commercial = 435	Social science	4-year public university (United States)	No subgroup analyses
Colvard et al. (2018)	Open = 10,141, commercial = 11,691	Varied	4-year public university	No assessment of prior knowledge or achievement
Grewe and Davis (2017)	Open = 95, commercial = 95	Humanities	2-year public college (United States)	No subgroup analyses; different instructors
Grissett and Huffman (2019)	Open = 36. commercial = 34	Social science	4-year public university (United States)	Small sample sizes
Hendricks et al. (2017)	Open = 787, commercial = 1,583	Hard science	4-year public university (Canada)	No analysis of possible differences in scientific attitudes
Hilton and Laman (2012)	Open = 370, commercial = 370	Social science	2-year community college (United States)	Inferential statistics not reported; no assessment of prior knowledge or achievement; courses were redesigned along with adoption of an open-source textbook
Hilton et al. (2013)	Open = 2,043, commercial = 4,164	Math	2-year community college (United States)	Confound of changes in course placement policies; inferential statistics not reported
Hilton et al. (2016)	Open = 2,014, commercial = 43,223	Varied	2-year community college (United States)	Different instructors taught courses with OER and commercial textbooks
Jhangiani et al. (2018)	Open = 139, commercial = 105	Social science	4-year public university (Canada)	Summer terms were compared with academic year, may be a different population
Lawrence and Lester (2018)	Open = 193, commercial = 243	Social science	4-year public university (United States)	Limited reporting of descriptive and inferential statistics for grades; no assessment of prior knowledge or achievement

Note. Sample size may vary between withdrawal rate and learning performance measures for the same studies depending on who was included in the authors' samples and differences in available data.

For the learning measure, if course grades and learning measures included in the overall course grades were reported (e.g., exam scores), then only course grades were used in the meta-analysis. This was to avoid redundant effect sizes because course grades are inclusive of performance on learning measures within a course (note that Medley-Rath, 2018, had a posttest measure that was not included in the final grade). One exception is Allen and colleagues (2015), because the information to calculated effect sizes based on a standardized learning measure was available, but such information was not available for course grades. However, there were studies in which multiple measures were reported that had separate scores (e.g., Hardin et al., 2019; Jhangiani et al., 2018). These measures were not independent because they came from the same samples. To account for these multiple measures that were from the same study (but were separate measures), robust variance estimation (RVE) was used. RVE is a method of incorporating correlations of dependent effect sizes within studies. This approach is more accurate for estimating effect sizes than the traditional approach of aggregating multiple effect sizes within a study (Tanner-Smith, Tipton, & Polanin, 2016). Also, a small sample correction was used (Tipton, 2015; see Tipton & Pustejovsky, 2015). The package "robumeta" was used (Fisher & Tipton, 2014). There were 22 studies with 26 measures (and subsequently 26 effect sizes) assessing learning efficacy.

For the withdrawal information, the odds ratio was used to compare the odds of withdrawal in a course that uses commercial textbooks compared with one that uses open textbooks (see Freeman et al., 2014, for a similar approach). The

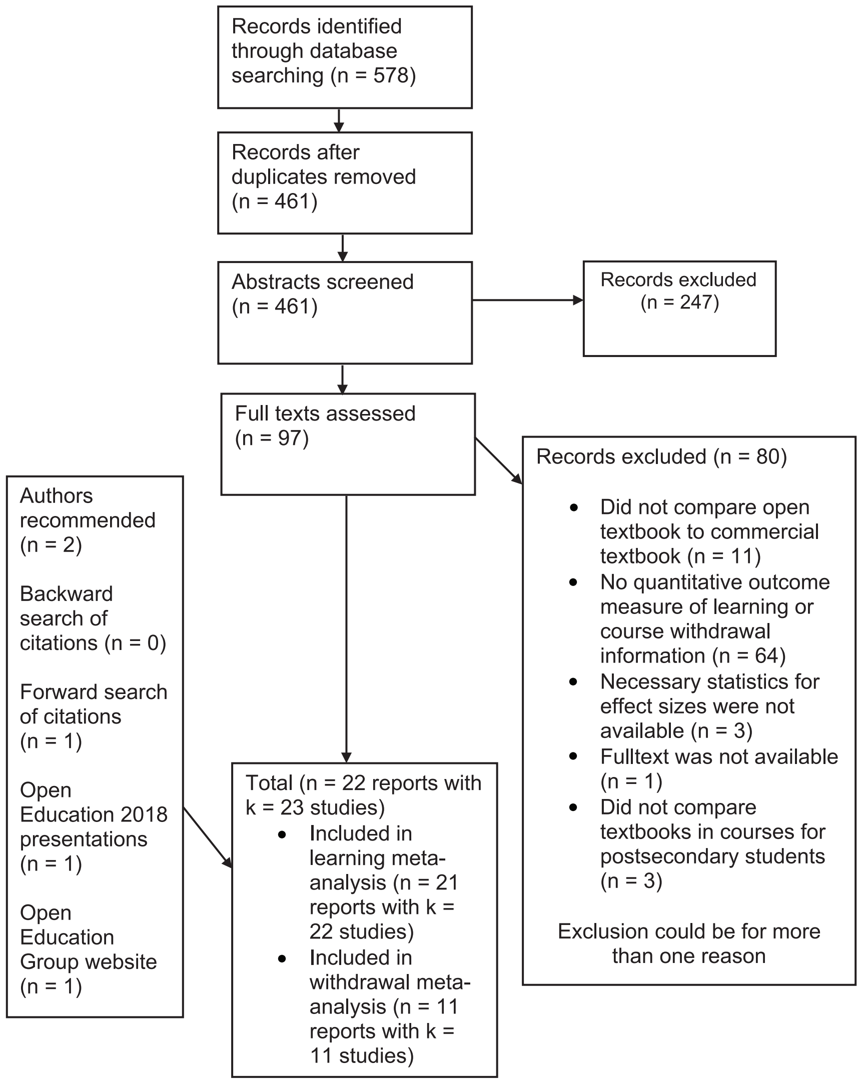

FIGURE 1. *Flow diagram of the systematic review process.*

odds ratio was chosen because findings regarding withdrawal rates, unlike learning measures, were always reported as dichotomous variables. Because there was only one measure of withdrawal rate (and subsequently only one effect size) per the study, RVE was not used. The odds ratio indicates the relative odds of withdrawal rate associated with the type of textbook used. An odds ratio less than 1 indicates that the use of open textbooks in courses was associated with a lower withdrawal rate compared with commercial textbooks. The withdrawal rate was reported in five studies and provided by authors on request for an additional six studies (i.e., the withdrawal rate not stated in the dissemination, but six authors whose reports were included in the learning efficacy meta-analysis were able to locate and share the relevant numbers regarding course withdrawals).

The I^2 index was used to report the heterogeneity of effect sizes. The I^2 index ranges from 0 to 100 and indicates the percentage of heterogeneity across studies not due to chance or sampling error—higher levels indicating a greater degree of heterogeneity. Moderator analyses were appropriate if the I^2 index is more than 20% (Bloch, 2014).

Results

Learning Efficacy

See Appendix C for R code used in analyses and for data sets. A data dictionary for the data sets is also provided in Appendix C.

Outliers in the effect sizes were examined using a violin plot prior to synthesizing effect sizes in RVE (see Tanner-Smith et al., 2016). To construct the violin plot, the package vioplot was used (Adler & Kelly, 2018). A violin plot is a combination of a box plot, which displays a measure of central tendency (either mean or median) and interquartile range, and a kernel density plot, which has a smooth curve to indicate the probability density of a variable in a manner similar to a histogram (Hintze & Nelson, 1998). This allows for a visual display of the distribution of the data as well as the summary statistics. The violin plot, shown in Figure 2, has a white circle to indicate the mean and the thin black line to represent the interquartile range. Weights were not used, but the data displayed in the violin plot, Hedges's *g*, were themselves biased correct for sample size. The violin plot, shown in Figure 2, is normally distributed and slightly left skewed. The effect sizes outside of the thin gray line indicate that there were outliers. However, this was approximately evenly distributed on both sides, and all effect sizes were included so as not to lose information (e.g., Kong, Seo, & Zhai, 2018).

The learning performance overall was first examined, and the I^2 was 98.17, which would indicate a substantial amount of heterogeneity. Based on the results of the RVE meta-analysis assuming correlated effects of .8, there were no reliable differences in learning performance between students in courses with open textbooks compared with students in courses with commercial textbooks, $g = 0.01$, *SE* (standard error) = 0.08, 95% CI (confidence interval) = [−0.16, 0.19], $p = .87$ (see Table 3 for findings by study).

To further examine the null effect found, two approaches were used. The first was a power analysis (Harrer & Ebert, 2018). Based on a small effect size of Cohen's $d = 0.2$, the average number of participants in each study, the number of studies, and a high degree of heterogeneity, the power was 1—indicating a great likelihood that there was sufficient power to detect a small effect. However, there was substantial variability with the number of participants in each study. Given this, the analysis was redone with the same variables except that the median number of participants in each study was used. Again, the power was 1.

The second examination was an equivalence test using the package "toster" in R (Lakens, Scheel, & Isager, 2018). The equivalence test was significant, $Z = -2.25$, $p = .01$, assuming a small effect size of Cohen's $d = 0.2$. An interpretation of this finding was that the main effect of learning performance in courses with open textbooks compared with those with commercial textbooks was statistically equivalent to zero.

Publication bias, which is the increased likelihood that statistically significant findings were reported, was assessed in two manners using aggregated effect sizes because there currently is not a validated measure of publication bias with RVE (Friese, Frankenbach, Job, & Loschelder, 2017). The first was the graphical technique of the funnel plot. A funnel plot shows studies graphed according to their size along the *y*-axis in which smaller studies were toward the bottom, and the effect sizes were along the *x*-axis. The line in the middle represents the mean effect. If there were an asymmetrical distribution on the sides of the

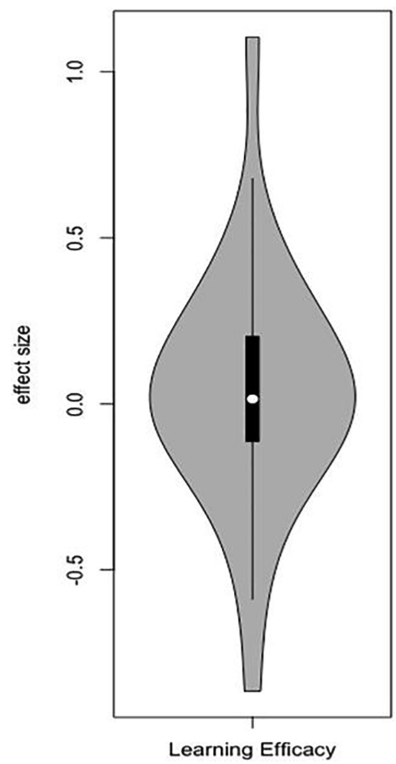

FIGURE 2. *Violin plot for learning performance studies.*

middle line and/or if the distribution of studies was broader at the bottom, then publication bias was likely (Egger, Smith, Schneider, & Minder, 1997). Based on the funnel plot in Figure 3, there did not appear to be publication bias. Publication bias was also tested quantitatively using Egger's test of the intercept, which did not differ significantly from zero, $\beta = -1.49$, 95% CI [−5.12, 2.13], $p = .40$, indicating unlikely publication bias (Cooper, 2015; see Follmer, 2018; Koponen, Georgiou, Salmi, Leskinen, & Aro, 2017, for similar approaches for testing publication bias).

Moderator Analyses. To test for potential moderators, a meta-regression model with each of the moderators as coefficients was estimated (see Tipton & Pustejovsky, 2015). Following Borenstein, Hedges, Higgins, and Rothstein (2009), a minimum of six effect sizes per potential moderator category was required to conduct moderator analyses (see Elleman, 2017, for a similar approach). Therefore, potential moderators such as the same course being compared and whether the learning measure was part of a course grade or only for a research study (e.g., for the studies in Gurung, 2017) were not examined.

The moderators examined were whether the instructor was the same for open and commercial conditions, whether prior knowledge or prior student achievement was considered or controlled in the analyses, and whether the learning measure was identical (e.g., the same exam was used) for

TABLE 3

Learning Efficacy Statistics for Each Study and Model Statistics (Positive Hedges's g Indicates Better Performance With an Open-Source Textbook Compared With a Commercial Textbook)

Study Name	Same Instructor(s)	Prior Achievement	Identical Learning Measure(s)	Hedges's *g*	*SE*	Sample Size O	C	T
Allen et al. (2015)	Yes	Yes	Yes	0.02	0.07	377	348	725
Basu Mallick et al. (2018)	No	No	No	−0.14	0.02	4247	14474	18,721
Chiorescu (2017)	Yes	No	No	0.20	0.14	159	447	606
Choi and Carpenter (2017)	Yes	No	No	−0.44	0.12	175	114	289
Clinton (2018)	Yes	No	No	0.23	0.09	204	316	520
Colvard et al. (2018)	Yes	No	No	0.21	0.01	10,141	11,681	12,692
Engler and Shedlosky-Shoemaker (2019)	Yes	Yes	Yes	0.00	0.28	24	25	49
Feldstein et al. (2012)	No	No	No	0.20	0.05	1,394	2,176	3,570
Grewe and Davis (2017)	No	Yes	No	1.104	0.20	58	60	118
Grissett and Huffman (2019)	Yes	No	Yes	−0.16	0.26	31	29	60
Gurung (2017), Study 1	No	Yes	Yes	−0.87	0.07	405	398	803
Gurung (2017), Study 2	No	Yes	Yes	−0.48	0.07	823	584	1,407
Hardin et al. (2019),[a] content knowledge	No	No	Yes	0.39	0.05	682	1122	1704
Critical thinking				0.06	.06	332	1115	1447
Aggregated				0.22	.06	507	1118.5	1575.5
Hendricks et al. (2017)	Yes	No	No	0.12	0.05	755	750	1505
Hilton et al. (2013)	Yes	No	No	−0.09	0.30	2,043	4,164	6,207
Hilton et al. (2016)	No	No	No	0.12	0.03	2,014	43,223	45,237
Jhangiani et al. (2018), Exam 1	No	Yes	Yes	0.01	0.15			
Exam 2				0.02	0.15			
Exam 3				0.52	0.15			
Aggregated				0.18	0.15	94	83	177
Lawrence and Lester (2018)	Yes	No	No	−0.06	0.10	178	200	378
Medley-Rath (2018), posttest	Yes	Yes	Yes	−0.21	0.29			
Course grade	Yes	No	Yes	0.36	0.39			
Aggregated				0.08	0.29	23	24	47
Robinson (2015)	No	No	No	−.12	.03	1908	1908	3816
Westermann Juárez and Venegas Muggli (2017)	Yes	No	No	−.10	.04	31	30	61
Winitzy-Stephens and Pickavance (2017)	No	No	No	−.02	.06	329	1120	1449
Random model (all $k = 22$)				.01	.08	25,920	83,272.5	100,012.5

Note. Prior achievement = study either incorporated measure of prior knowledge and/or achievement into findings or conducted analyses to determine no significant differences by condition in prior knowledge and/or achievement. Sample size O = open textbook, C = commercial textbook, and T = sum of students; *SE* = standard error.

[a]Some students took both measures and some were randomly assigned to only take one. In the interests of being conservative, the aggregated sample size consists of the mean of the sample sizes for the two measures.

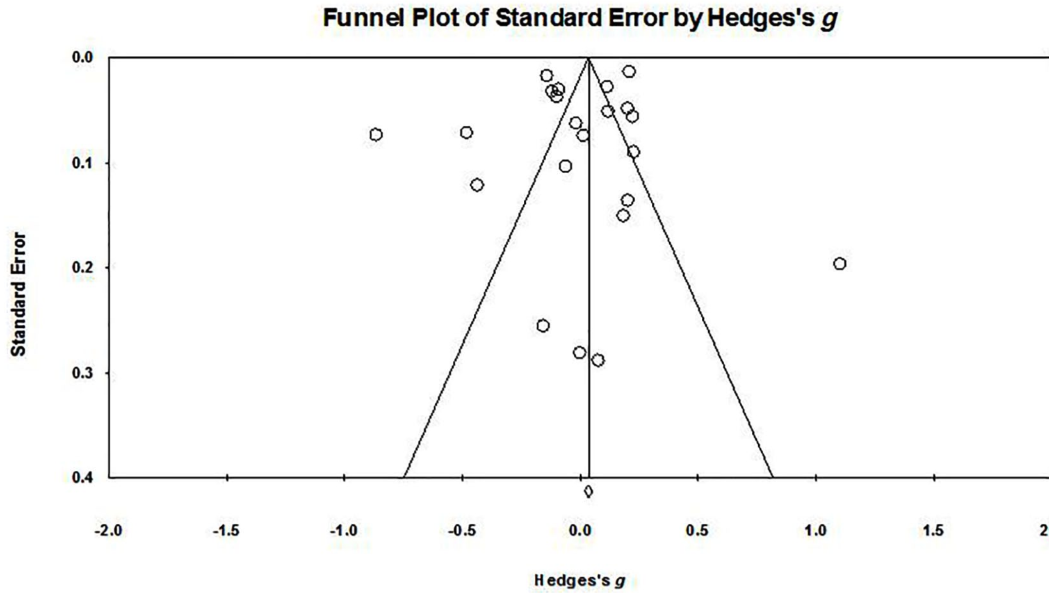

FIGURE 3. *Funnel plot for learning performance studies.*

TABLE 4
Meta-Regression Results for Learning Efficacy

	β	*SE*	*T*	*df*	*p*	95% CI Lower	95% CI Upper
Intercept	−0.03	0.1	−0.26	13.27	.80	−0.24	0.19
Prior	0.22	0.52	0.43	3.54	.69	−1.30	1.74
Instructor	−0.02	0.15	−0.122	14.81	.91	−0.35	0.31
Measure	−0.39	0.46	−0.83	3.34	.46	−1.78	1.01

Note: Prior = study either incorporated measure of prior knowledge and/or achievement into findings or conducted analyses to determine no significant differences by condition in prior knowledge and/or achievement. Instructor = whether or not the same instructor taught the courses with open or commercial textbooks. Measure = whether or not the measure for learning efficacy was identical for courses with open or commercial textbooks. *SE* = standard error; *T* = *t*-test value; *df* = degrees of freedom; 95% CI Lower = 95% confidence interval lower limit; 95% CI Upper = 95% confidence interval upper limit.

open and commercial conditions. Each of these potential moderators pertains to methodological quality. Note that Clinton (2018) was coded as "does not consider prior knowledge or prior academic performance" because the measure of student prior knowledge was significant between conditions and could not be covaried out of the effect size (data were only available at the course level, it was not possible to get student-level data). As can be noted in Table 4, none were significant. However, there were fewer than 4 degrees of freedom for the results with prior knowledge or prior student achievement as well as for whether the learning measure was identical. With fewer than 4 degrees of freedom, the results cannot be trusted, and therefore, it was inconclusive whether these two moderators have effects. In addition, it is not good practice to conduct a power analysis for moderators in a meta-regression (Pigott, 2012); therefore, it is uncertain whether the findings for instructor indicated that there is truly no difference or if there was simply a lack of power to detect a difference.

Withdrawal Rate

For the withdrawal rate, the heterogeneity of effect sizes was substantial, with an I^2 of 83.09, which indicated that the findings varied considerably. Based on the random-effects model using the package "meta" (Schwarzer, 2007), the withdrawal rate for students in courses with open textbooks was lower than that of students in courses with commercial textbooks; OR (odds ratio) = 0.71, $k = 11$, 95% CI [0.56, 0.90], $p = .005$ (see Table 5 for statistics by study). As with learning efficacy, a violin plot was made to examine outliers. As can be seen in Figure 4, the distribution of effect sizes was quite negatively skewed, indicating likely outliers. However, the outliers were opposite the direction of the

TABLE 5

Withdrawal Rate Statistics for Each Study and Model Statistics (Odds Ratio <1 Indicates Lower Withdrawal Rate With an Open Textbook Than a Commercial Textbook)

Study Name	Withdrawal Published	Odds Ratio	95% CI Lower Limit, Upper Limit	*p*	Sample Size O	C	T
Chiorescu (2017)	Yes	0.5	0.23, 1.08	.08	159	447	606
Clinton (2018)	Yes	0.36	0.23, 0.57	<.001	232	435	667
Colvard et al. (2018)[a]	No	0.82	0.73, 0.93	.002	10,141	11,681	21,822
Grewe and Davis (2017)	No	0.56	0.25, 1.26	.16	95	95	190
Grissett and Huffman (2019)	No	3.00	0.30, 30.35	.35	36	34	70
Hendricks et al. (2017)	No	0.75	0.48, 1.17	.21	787	1,583	2,370
Hilton and Laman (2012)	Yes	0.46	0.28, 0.76	.002	370	370	740
Hilton et al. (2013)	Yes	1.23	1.09, 1.38	.001	2,043	4,168	6,211
Hilton et al. (2016)	Yes	0.97	0.84, 1.12	.68	2,014	43,223	45,237
Jhangiani et al. (2018)	No	0.44	0.10, 1.89	.27	139	105	244
Lawrence and Lester (2018)	No	0.51	0.25, 1.03	.06	193	243	436
Random model (*k* = 11)		0.71	0.56, 0.90	.005	16,209	62,384	78,593

Note. Withdrawal published is whether or not the withdrawal rate was reported in the publication (Yes) or the authors provided the withdrawal rate on request (No). Sample size O = open textbook, C = commercial textbook, and T = sum of students.
[a]Withdrawal rate was published as part of a composite measure including grades of D and F (DFW rate), but specific withdrawal rate analyses were not reported.

main effect. Therefore, the overall finding (that the withdrawal rate is lower for students in courses with open textbooks compared with commercial textbooks) was not affected by the outliers. For that reason and to not lose information, the outliers were kept in the analyses.

For withdrawal rate, over half of the studies did not report this information (it was obtained from the authors). Therefore, examining publication bias in a manner similar to what was done with learning efficacy (i.e., funnel plot and Egger's test of the intercept) would be inappropriate given that half of the findings were not published.

Discussion

The purposes of these meta-analyses were to summarize the efficacy of open textbooks compared with commercial textbooks on learning performance and withdrawal rate. Based on the findings of 22 independent studies, there appeared to be no effect on learning performance in courses with open textbooks compared with courses with commercial textbooks. This effect did not appear to vary between studies based on having the same instructors for the courses with open and commercial textbooks. However, it should be noted that the absence of a significant effect from a moderator may be due to a lack of power rather than a true null effect (Hempel et al., 2013). The moderator analyses for incorporating prior student performance into the analyses or using identical instruments for measuring learning for open and commercial textbook conditions were inconclusive. The withdrawal rate from courses with open textbooks, based on 11 independent studies, was reliably lower than that for courses with commercial textbooks.

The null results for learning performance from open compared with commercial textbooks supports the notion that open textbooks save students money without a detrimental effect on learning. This quantitative summary of the findings converges with conclusions based on qualitative systematic reviews comparing learning in courses with open and commercial textbooks (Hilton, 2016, 2018). Furthermore, this meta-analysis builds on these previous reviews by comparing effect sizes based on study quality through moderator analyses. These moderator analyses indicated that controlling for the confounder of whether or not the instructor was the same did not significantly vary the results. Therefore, although many studies on open textbooks have been justifiably critiqued for methodological quality (see Griggs & Jackson, 2017; Gurung, 2017, for critiques), this particular confounder did not appear to be skewing the findings on open textbook efficacy. However, this could be due to lack of power, and there was not sufficient power to trust the results for the other potential moderators examined (identical learning measure and whether or not student prior achievement was controlled).

Based on the access hypothesis, students in courses with open textbooks should be academically outperforming their peers in courses with commercial textbooks. This is because every student would have access to open textbooks, but some students would not be able to afford access, or at least reliable access, to a commercial textbook. However, the findings from this meta-analysis do not provide support for

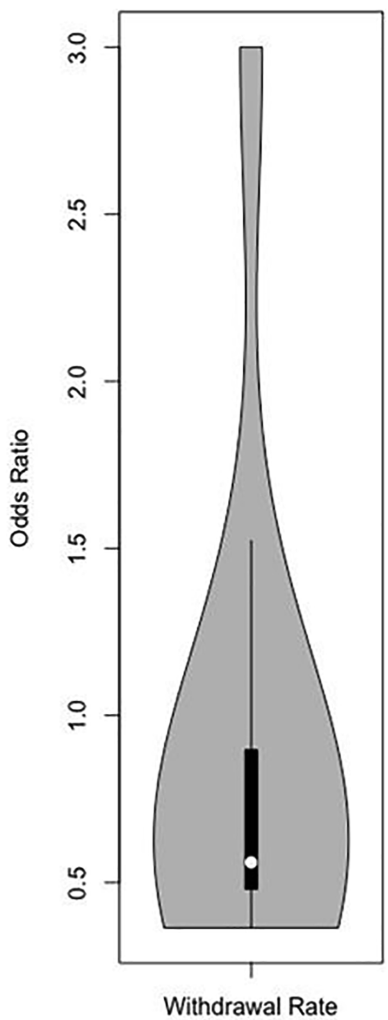

FIGURE 4. *Violin plot for withdrawal rate studies.*

this hypothesis. One reason could be that having free access to a textbook may only have a benefit for learning for a small number of students. For example, Colvard and colleagues (2018) found that students eligible for federal assistance grants based on low household income yielded greater learning benefits from open textbooks relative to their peers with higher household incomes. It could be that if the information on student socioeconomic status (SES) were available, SES would be a significant moderator in which students with lower SES backgrounds would have benefits not seen with students of higher SES who can more easily afford and access commercial textbooks. Alternatively, it is possible that the open and commercial textbooks compared were of similar quality and perhaps access was not necessarily an issue, so the learning findings were similar. Another possible reason, based on conjecture, is that postsecondary instructors may be aware that not all of their students have the commercial textbook and adjust their pedagogy accordingly. For example, instructors may be less likely to require reading or assignments requiring the use of the textbook if they are concerned about the financial impact on some of their students. Finally, it could also be possible that the type of textbook simply has little influence on student learning. For example, one experiment comparing commercial textbooks from different publishers found no differences between types in learning from reading them (Durwin & Sherman, 2008). This possibility is supported by findings from studies on open textbook efficacy (not eligible for this meta-analysis) in which all students had access to the commercial textbooks, but there were either no differences or a small benefit in learning performance with open textbooks (Clinton, Legerski, & Rhodes, 2019; Robinson, Fischer, Wiley, & Hilton, 2014).

Although there was no benefit of open textbooks on the performance of students who completed courses, there was a significant reduction in the likelihood of students withdrawing from the course. The most common reason students state for course withdrawal is that they anticipate failing the course or receiving a low grade (Wheland, Butler, Qammar, Katz, & Harris, 2012). It is possible that having access to a textbook may help a student who is behind to cover missed material and not withdraw from the class. In this way, students who are struggling in a course may be less likely to withdraw if they can access an open textbook for free as opposed to paying hundreds of dollars for a commercial textbook to succeed in the course. However, there should be caution with interpreting withdrawal findings because some studies compared courses with different instructors (e.g., Hilton et al., 2016; Wiley, Williams, DeMarte, & Hilton, 2016), and there were not enough studies in each cell to conduct moderator analyses.

Although not identified as an outlier in analyses, there was one study in which the withdrawal rate was significantly higher in a mathematics course with an open textbook than with a commercial textbook (Hilton et al., 2013). In the discussion of this finding, Hilton and colleagues (2013) describe how institutional policy changes for placement in mathematics courses coincided with the adoption of an open textbook for that course. This led to students with different levels of preparedness in mathematics in the compared courses, which creates a clear confounder for comparing withdrawal rates.

Limitations and Future Directions

There are a number of limitations in these meta-analyses as well as in research on open textbooks more generally that should be acknowledged. One limitation of this learning efficacy meta-analysis was the focus on postsecondary students. As with postsecondary education, the adoption of open textbooks in K–12 education can yield significant cost savings, even with the time involved with modifying curricula and pedagogy (Wiley, Hilton, Ellington, & Hall, 2012).

Furthermore, one study found that K–12 teachers rated open textbooks as better quality than commercial textbooks (Kimmons, 2015) and another found that K–12 teachers saw open textbooks as helpful when personalizing student learning (de los Arcos, Farrow, Pitt, Weller, & McAndrew, 2016). However, there is only one study that examined K–12 student learning that we know of that would have otherwise met the criteria to be included in this meta-analysis (Robinson et al., 2014). The increased focus on open textbooks in postsecondary education may be because the costs of commercial materials are more obvious to postsecondary students who typically have direct expenses for course materials, whereas the cost to public K–12 students are indirectly supported through taxpayers. That said, with more OER being developed for and used in K–12 schools (Pitt, 2015), more inquiry in their efficacy is needed (see Blomgren & McPherson, 2018, for a review of K–12 OER research on a variety of issues).

The geographic scope of this meta-analysis was not representative of OER use. The reports in this meta-analysis were based on studies set in the United States and Canada, with one exception of a study based in Chile (Westermann Juárez & Venegas Muggli, 2017). The advocacy and use of OER, including open textbooks, is international (Bliss & Smith, 2017). Furthermore, teaching and learning practices with textbook use vary considerably by geographic region, partly due to textbook availability (Milligan, Tikly, Williams, Vianney, & Uworwabayeho, 2017). It is unclear if open textbooks would ameliorate difficulties with textbook availability in regions in which access to the internet and electronic devices may be limited (Butcher, 2015). For these reasons, more inquiry into open textbook efficacy is needed outside the United States and Canada.

One limitation in the methodology of this meta-analysis is the use of a single screener for abstract screening. Logically, more than one screener would certainly reduce the likelihood a relevant citation was missed. Therefore, it is possible a relevant report was missed during abstract screening due to the use of a single screener. That said, an assessment of Abstrackr, the abstract screening software used in this meta-analysis, used only one screener (Gates, Johnson, & Hartling, 2018). Moreover, other possibly relevant reports were searched for in alternative methods (e.g., backward and forward citations searches) that may have compensated for the use of a single screener.

There were no significant moderators identified in the meta-regression analyses. However, there was substantial variability in the findings that would indicate the possible existence of significant moderators. It is possible that as more research is conducted in OER, there would be sufficient power to find that the proposed moderators related to study methodological quality explained some of this variability. In addition, future research could consider possible moderators, such as student background and how the textbook is used by the instructor and students, to determine sources of variability in findings.

Another reason for the variability could be that the studies themselves were quite different. Although all studies compared students enrolled with courses with open textbooks with those with commercial textbooks, there was a broad range of content areas and sample sizes. Moreover, grading criteria vary considerably among instructors and institutions. Regarding course withdrawals, each institution in this study had an initial drop period without a withdrawal on the transcript at the beginning of the term and a deadline at some point in the term to receive a W and not an F. However, the specific deadlines and policies varied.

The noted differences in the course withdrawal rates for open and commercial textbooks may have subsequently led to the characteristics of the students who completed the courses to be different. Although it is possible that students opted not to withdraw because they had access to an open textbook that allowed them to perceive a better chance of success in the course, in general, students who withdraw tend to have weaker academic backgrounds than those who persist in courses (McKinney, Novak, Hagedorn, & Luna-Torres, 2019). It is possible that this could lead to student differences in the courses that cannot be accounted for in the data available for these meta-analyses.

A potential issue is the medium (paper or screen) from which students read their course textbook. In Gurung's (2017) second study, the performance between students in courses using open textbooks was lower than students in courses using commercial textbooks. However, the difference was much smaller when only examining students who accessed their textbooks only electronically (thus reading from screens). Because open textbooks are free to access electronically but involve costs for hard copies, it may be that students may be more likely to read their open textbooks electronically than commercial textbooks (that involve costs in any medium; Clinton, 2018). This issue of reading medium used may be worth considering given that meta-analyses have been published indicating a small benefit in learning performance when reading from paper compared with reading from screens (Clinton, 2019c; Kong et al., 2018).

Conclusion

Open-source textbooks have been developed primarily in response to the rising costs of commercial materials. Concerns over quality and effects on learning have prompted numerous studies in this area. Based on the meta-analytic findings here, there are no meaningful differences in learning efficacy between students using open textbooks and students using commercial textbooks. However, students in courses with open textbooks appear to be less likely to withdraw. There are several limitations in research on open textbooks that indicate future research should consider K–12 students, the needs of students outside of the United States and Canada, and the potential moderating factors of student characteristics.

Appendix A

Search Terms Used for Each Database

Scopus
"open source textbook*"
"OER" + textbook*

ERIC
"open source textbook*"
"OER" + textbook*

DOAJ
"open source textbook*"
"OER" + textbook*

ProQuest
"open source textbook*"
"OER" textbook*

PSYCinfo
"open source textbook*"
"OER" textbook*

Appendix B

Coding of Studies

If the information was not available in the report, the corresponding author was contacted with a request for the information. If the information was not or could not be obtained, then the code "N/A" for "not available" was used.

Descriptive Information
See Tables 1 and 2

1. *Bibliographic information*: Authors, year of publication, and title
2. *Dissemination type*: Peer-reviewed journal article, master's thesis or dissertation, conference presentation or proceedings, or unpublished data
3. *Year of publication*: The year it was published or the necessary statistical information was provided
4. *Sample size*: Number of participants in each condition
5. *Type of learning measure*: Exam scores, course grade, researcher development measure, other
6. *Content area*: Social sciences, mathematics, hard sciences, humanities, vocational/business education, multiple, other
7. *Institution type*: K–12, public 2-year postsecondary, private 2-year postsecondary, public 4-year postsecondary, private 4-year postsecondary
8. *Country*: The country in which the study took place

Study Quality
See Table B1

1. Were the participants in the open textbook condition comparable with the participants in the commercial textbook condition? If yes, then there was a pretest or prior academic measure that was found to be similar across conditions or statistically controlled for in the analyses.
2. Were the participants in each condition receiving similar instruction? Specifically, the following three questions were asked:
   a. Were the courses in the open and commercial conditions the same?
   b. Were the instructors in the open and commercial conditions the same?
   c. Were the course modalities the same (online, face to face, blended)? Whenever possible, only courses of the same modality were included (e.g., Hendricks et al., 2017, involved one online course section with an open textbook, but all other courses were face to face so only courses of the same modality, face to face, were included).
3. To what extent was the intervention tested for effectiveness within important subgroups of participants? Specifically, were participant subgroups, such as variation in socioeconomic status or prior academic achievement examined?
4. Were the outcomes measured in a way that is consistent with the proposed effects of the intervention? If yes, the outcome measure (grades, exam scores, withdrawal rate) was relevant to the course(s) being compared in the study.
5. Did the description of the study give any other indication of the strong plausibility of other intervention contaminants? If yes, there was evidence of potential contaminants such as substantial course redesign or changes in institutional policies.
6. Were the sample sizes adequate to provide sufficiently precise estimates of effect sizes? If yes, there were at least 50 participants per condition.
7. To what extent were sample sizes reported (or estimable) from statistical information presented? If yes, sample sizes for each condition were explicitly reported.
8. To what extent could the direction of effects be identified for important measured outcomes? Specifically, were the direction of effects explicitly reported?
9. Were statistical tests adequately reported? If yes, the inferential statistics (e.g., F statistic, t tests, p values) were explicitly stated in the report.

TABLE B1

Study Quality Coding for Each Study

Authors (date)	1	2a	2b	2c	3	4	5	6	7	8	9	10	11
Allen et al. (2015)	Yes	Yes	Yes	No	No	Yes	No	Yes	Yes	Yes	Yes	For one measure	Yes
Basu Mallick et al. (2018)	No	Yes	No	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	No
Chiorescu (2017)	No	Yes	Yes	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	No
Choi and Carpenter (2017)	No	Yes	Yes	Yes	No	Yes	No	Yes	Yes	Yes	No	Yes	No
Clinton, 2018	No	Yes	Yes	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	No
Colvard et al. (2018)	No	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	No
Engler and Shedlosky-Shoemaker (2019)	Yes	Yes	Yes	Yes	No	Yes	No	No	Yes	Yes	Yes	Yes	Yes
Feldstein et al. (2012)	No	No	No	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	No
Grewe and Davis (2017)	Yes	Yes	No	Yes	No	Yes	No	Yes	Yes	Yes	Yes	No	No
Grissett and Huffman (2019)	No	Yes	Yes	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes
Gurung (2017), Study 1	Yes	Yes	No	Not stated	No	Yes	No	Yes	No	Yes	Yes	No	Yes
Gurung (2017), Study 2	Yes	Yes	No	Not stated	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes
Hardin et al. (2019)	No	Yes	No	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes
Hendricks et al. (2017)	No	Yes	Yes	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	No
Hilton and Laman (2012)	No	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	No	For withdrawal rate	N/A
Hilton et al. (2013)	No	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	No	Yes	No
Hilton et al. (2016)	No	Yes	No	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	No
Jhangiani et al. (2018)	Yes	Yes	No	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes
Lawrence and Lester (2018)	No	Yes	Yes	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	No
Medley-Rath (2018)	Yes (for one measure)	Yes	Yes	Yes	No	Yes	No	No	Yes	Yes	Yes	Yes	Yes
Robinson (2015)	No	Yes	No	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	No
Westermann Juárez and Venegas Muggli (2017)	No	Yes	Yes	Yes	No	Yes	No	No	Yes	Yes	Yes	Yes	No
Winitzky-Stephens and Pickavance (2017)	No	No	No	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	No	No

Note. 1 = pretest or prior achievement measure indicate participants had similar backgrounds/preparation; 2a = same courses; 2b = same instructors; 2c = same modalities; 3 = subgroup analyses; 4 = relevant outcome measures; 5 = intervention contaminants; 6 = more than 50 participants per condition; 7 = sample sizes explicitly reported; 8 = direction of effects explicitly reported; 9 = inferential statistics explicitly reported; 10 = effect sizes could be computed; 11 = same assessment measure.

10. Could estimates of effect sizes be computed using a standard formula (or algebraic equivalent)? If yes, the necessary information was reported. If not, the corresponding author was contacted for the information. If the information for necessary effect sizes could not be obtained, the study could not be included in the meta-analysis.
11. Was the assessment measure for learning the same for students with open textbooks and those with commercial textbooks? If yes, the learning measure was identical.

Appendix C

Data Dictionary

Learning Data Set

Variable Name	Description
studynum	Study number
ES.ID	Effect size ID number
Author	Study author
Measure	Effect size description
effect.size	Hedges's *g* effect size
var	Variance of effect size
prior	Prior knowledge measured (0 for no, 1 for yes)
Instructor	Instructor was the same for open textbook and commercial textbook (0 for no, 1 for yes)
measure	Measure was the same for open textbook and commercial textbook (0 for no, 1 for yes)

Withdrawal Data Set

Variable Name	Description
studynum	Study number
esnumber	Effect size ID number
Author	Study author
Ee	Number of withdrawals for commercial textbook
Ne	Total participants for commercial textbook
Ec	Number of withdrawals for open textbook
Nc	Total participants for open textbook
OR	Odds ratio
log	Log odds ratio
SE	Standard error
var	Variance of effect size

R Code for Analyses

```
install.packages("robumeta")
install.packages("devtools")
install.packages("vioplot")
install.packages("grid")
install.packages("meta")
install.packages("vioplot")
install.packages("TOSTER")
library(robumeta)
library(devtools)
library(vioplot)
library(grid)
library(meta)
library(vioplot)
library(TOSTER)

data <- read.csv("learning.csv") #reading in the data
names(data) #reads off the variable names in your dataset
is.numeric(data$Follow.Up)
levels(data$Follow.Up)

is.numeric(data$prior)
summary(data$prior)

is.numeric(data$instructor)
summary(data$instructor)

is.numeric(data$measure)
levels(data$measure)
#RVE analyses for main effect testing of learning efficacy
#Fisher Z., Tipton E. (2014). robumeta: An R-package for robust variance estimation in meta-analysis. Retrieved from arXiv preprint arXiv:1503.02220

learning <- robu(formula = effect.size ~ 1, data = data, studynum = studynum, var.eff.size = var, rho = .8, modelweights = "CORR", small = TRUE)

print(learning)


####POWER ANALYSIS
#####Harrer, M. & Ebert, D. D. (2018). Doing Meta-Analysis in R: A practical Guide. PROTECT Lab Friedrich-Alexander University Erlangen-Nuremberg. https://bookdown.org/MathiasHarrer/Doing_Meta_Analysis_in_R/

power.analysis.random<-function(d,k,n1,n2,p,heterogeneity){

  n1<-n1
  n2<-n2
  d<-d
  k<-k
  p<-p
  heterogeneity<-heterogeneity
  if(heterogeneity=="low"){

    v.d<-((n1+n2)/(n1*n2))+((d*d)/(2*(n1+n2)))
    v.m<-v.d/k
    v.m<-1.33*v.m
    lambda<-(d/sqrt(v.m))
    plevel<-1-(p/2)
    zval<-qnorm(p=plevel, 0,1)
    power<-1-(pnorm(zval-lambda))+(pnorm(-zval-lambda))
    return(power)
  }

  if(heterogeneity=="moderate"){

    v.d<-((n1+n2)/(n1*n2))+((d*d)/(2*(n1+n2)))
```

```
        v.m<-v.d/k
        v.m<-1.67*v.m
        lambda<-(d/sqrt(v.m))
        plevel<-1-(p/2)
        zval<-qnorm(p=plevel, 0,1)
        power<-1-(pnorm(zval-lambda))+(pnorm(-zval-lambda))
        return(power)
    }

    if(heterogeneity=="high"){

        v.d<-((n1+n2)/(n1*n2))+((d*d)/(2*(n1+n2)))
        v.m<-v.d/k
        v.m<-2*v.m
        lambda<-(d/sqrt(v.m))
        plevel<-1-(p/2)
        zval<-qnorm(p=plevel, 0,1)
        power<-1-(pnorm(zval-lambda))+(pnorm(-zval-lambda))
        return(power)
    }

}
power.analysis.random(d=0.20,k=22,n1=1178,n2=3785,p=0.05,
                      heterogeneity = "high")
power.analysis.random(d=0.20,k=22,n1=353,n2=423,p=0.05,
                      heterogeneity = "high")
####non equivalence test
###Lakens, D., Scheel, A. M., & Isager, P. M. (2018). Equivalence Testing for Psychological Research: A Tutorial. Advances in Methods and Practices in Psychological Science, 1(2), 259-269. https://doi.org/10.1177/2515245918770963

TOSTmeta(ES = 0.0136, se = 0.0827, low_eqbound_d=-0.1, high_eqbound_d=0.1, alpha=0.05)

print(TOSTmeta)

TOSTmeta(ES = 0.0136, se = 0.0827, low_eqbound_d=-0.2, high_eqbound_d=0.2, alpha=0.05)

####META REGRESSION

data$prior_c <- data$prior - mean(data$prior)
data$instructor_c <- data$instructor - mean(data$instructor)
data$measure_c <- data$measure - mean(data$measure)

res_4<-robu(formula = effect.size ~ prior_c + instructor_c + measure_c, var.eff.size=var, studynum =
                studynum, modelweights = "CORR", rho =
                0.8, small=TRUE,
            data=data)
print(res_4)
Wald_test(res_4, constraints = 2:3, vcov="CR2")

####OUTLIER learning efficacy, Daniel Adler and S. Thomas Kelly (2018). vioplot: violin plot. R package version 0.3.0 https://github.com/TomKellyGenetics/vioplot

vioplot(data$effect.size, col="grey", names="Learning Efficacy")
title(ylab="effect size")

###Odds ratio
##package meta Schwarzer, G. (2007). Meta: An R package for meta-analysis. R News, 7(3), 40–45. https://cran.r-project.org/doc/Rnews/Rnews_2007-3.pdf

data <- read.csv("withdrawal.csv") #reading in the data
WOR <- metabin(Ee, Ne, Ec, Nc, sm="OR", data = data)
summary(WOR)

vioplot(data$OR, col="grey", names="Withdrawal Rate")
title(ylab="Odds Ratio")
```

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Interactive electronic textbook use in higher education: grades, engagement, and student perceptions

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Abstract: A trend towards electronic textbooks (e-textbooks) in higher education has given cause for additional research regarding their effectiveness when compared with traditional print textbooks. There is a lack of research specifically regarding interactive e-textbooks – texts that have been enriched with embedded links, videos, quizzes, or other activities. This study presents the findings from an introductory education course within a large university in the USA that began using an interactive e-textbook as the dominant text for the course. Correlation was measured between student grades and three different elements of an interactive electronic textbook: total time spent logged into the e-textbook, student engagement level, and percent of interactive activities accessed. Student perceptions of the e-textbook were also gathered. Results showed significant positive correlation between overall course grades and two of the three variables tested (time and engagement). Survey results revealed a high level of comfort and convenience using the interactive e-textbook.

Keywords: electronic textbooks; e-textbooks; interactive textbooks; engagement; textbooks; grades; learning; higher education; student perceptions; print textbooks; time; activities.

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1 Introduction

Mobile device use is continually rising, electronic books (e-books) and tablets are becoming more prevalent, and the use of electronic textbooks (e-textbooks) has been increasing in many academic settings – especially within higher education institutions (Daniel and Woody, 2013). These trends have resulted in an increased number of courses offering digital textbooks as the main resource to support student learning (Rockinson-Szapkiw et al., 2013). As indication of the growing prevalence of electronic textbook usage, a recent study at a large university showed that the majority of students have used e-textbooks in their college studies (Seilhamer, 2016), while Henderson et al. (2016) found that nearly 85% of students within their study reported using e-books and e-textbooks.

Interactivity within electronic textbooks includes multimedia elements such as video, animations, links, personalised learning, and embedded quizzes (Weng et al., 2018). Publishers are constantly striving to update and add to the interactive features included within e-textbooks to make them more attractive to students and institutions, and it appears to be working. The use of digital textbooks is becoming so commonplace that some textbook publishers only offer e-textbook versions now, which forces schools that have been slow to embrace this change down the electronic path (Minnich et al., 2015). Considering this shift towards electronic texts, decision-makers in higher education need to consider the benefits and hindrances related to the adoption of these increasingly interactive e-textbooks.

1.1 Evolution of electronic textbooks

When e-books and e-textbooks first entered the educational scene, they were typically electronic replications of the printed text, i.e., they were read linearly in the same manner as print texts. These e-books are called 'page-fidelity' texts, defined as a basic PDF replica of the print version (Rockinson-Szapkiw et al., 2013). With the advancement of technology has come the enhancement of these digital texts to make them more active and engaging. Now, many e-textbooks are enhanced with hypertext, images, videos, and interactive elements for students to explore. These versions are called 'reflowable', and they provide a flexible system where the reader can affect the layout and can manipulate various interactive features within the text (Rockinson-Szapkiw et al., 2013). These built-in features can potentially provide a strong benefit over print texts and offer more active learning opportunities for students.

According to O'Loughlin (1992), active learning involves student-centred participatory learning, and commonly includes interpersonal interactions between students (Chickering and Gamson, 1987). More recently, theories of active learning involving technologies such as simulations, smartphones, games, and tablets have emerged (Dyson et al., 2009; Laird and Kuh, 2005; Scott et al., 2009). These sub-theories focus on constructs such as autonomy, student-control, self-regulation, engagement, and student-directed learning that are facilitated by and through the use of technologies (Chi, 2009; Hagel et al., 2012; Rae and Cochrane, 2008).

'Reflowable' digital textbooks can support active learning. In addition to hypertext links, images, and videos, features of these interactive electronic textbooks allow learners the autonomy and ability to engage with a myriad of learning resources in a self-directed manner. These digital resources can also include vocabulary assistance (text narration, dictionary/glossary searches), digital models of the content described within the text, the ability to change font size, increased potential for collaboration with an instructor or student peers, and relevant quizzes which are synced with the course gradebook (Maynard and Cheyne, 2005). In addition, interactive e-textbooks help to motivate learners and to cultivate student engagement that results in collaborative learning and shared knowledge among students (Knight, 2015). All of these features can help to make studying and learning from a textbook more accessible, convenient, and connected with classmates, which promotes key theoretical constructs of active learning including autonomy, student-control, self-regulation, engagement, and student-directed learning.

1.2 General benefits

In addition to the active learning features that are provided, electronic textbooks offer several note worthy benefits when compared with traditional print textbooks. E-textbooks are typically less-expensive than the equivalent print textbook, and with textbook prices increasing by more than 80% in recent years (Minnich et al., 2015), students and university personnel have good reason to consider electronic versions. Additionally, many e-textbooks are available for free as open educational resources, making them attractive alternatives as the main texts for programs looking to save money (Minnich et al., 2015; Fischer et al., 2015).

Convenience is often reported as the most distinct advantage of e-textbooks: they are easily accessible and available (Hoseth and McLure, 2012); they are often downloaded onto the computer, thereby removing the need for uninterrupted internet access (Maynard and Cheyne, 2005); and they are possibly more current than print texts (Hoseth and McLure, 2012). E-textbooks are also more mobile than their print counterparts, they save space within libraries and university bookstores (Maynard and Cheyne, 2005), and they offer more usability (Connell et al., 2012).

1.3 General hindrances

Despite the aforementioned potential benefits of interactive texts, existing research shows there are several negatives surrounding e-textbook use in higher education. From a physical standpoint, Rockinson-Szapkiw et al. (2013) report that digital texts tend to take students longer to read and can cause higher levels of eyestrain. From a learning perspective, when static screen (i.e., non-interactive) e-texts have been studied in relation to traditional printed textbooks regarding learning impact, some research shows a decrease in fact retrieval and recall scores from students reading on a screen (Jeong, 2012), while other research shows no cognitive difference between electronic and print versions (Rockinson-Szapkiw et al., 2013), although students may read more slowly on a screen (Connell et al., 2012).

Another drawback to reading from a screen is the apparent tendency to skim the text instead of reading deeply (Morkes and Nielsen, 1997). Using an eye-tracking heat map, Nielsen (2006) discovered that readers typically skim electronic texts in an f-shaped pattern by first reading horizontally for a few lines, then scanning vertically down the left side of the page (for important headings and bold font), and then again horizontally. The major implication of this finding is that readers may not read electronic content as thoroughly as print (Nielsen, 2006); this presents a need for educators to investigate student engagement levels and time spent learning within electronic texts.

Another hindrance is the inability (sometimes actual, sometimes perceived) to take notes, highlight, or write in digital texts (Hoseth and McLure, 2012), which are strategies that have been associated with self-regulated learning (Kauffman et al., 2011). It appears that many earlier versions of e-textbooks did not have annotation features, but with the more recent proliferation of interactive e-textbooks, that hindrance might fade away.

Additionally, e-textbooks raise the issue of internet connectivity, because many e-textbooks require constant internet access (Hoseth and McLure, 2012). Now that most students seem to have smartphones and other mobile devices with cellular data, that issue may also become irrelevant. Of course, all of these hindrances to e-textbooks are important for educators to consider; however, the most important factor – one that is consistently in the minds of those involved in educational environments – is how these tools and features affect student learning.

1.4 Impact on learning

Improvements in mobile and interactive technologies have provided an opportunity for educational leaders to rethink how we learn most effectively, and these technologies can be a valuable asset for teachers and students at all levels of learning (Poon and Koo, 2010; Choi et al., 2007). Existing research has centred on the impact e-textbooks have on student learning. Maynard and Cheyne (2005) investigated the effect the screen had on both comprehension and reading speed. The study was designed to test participants' ability to understand and locate information within the text. Results showed no significant increase on individual performance between print and electronic groups; however, students reported that the electronic version made learning easier and more enjoyable (Maynard and Cheyne, 2005). These researchers conclude that e-textbooks provide advantages of interactivity and motivation. Specifically, the interactivity of e-textbooks excites students about learning, increasing motivation, curiosity, and engagement.

One measure of active learning has included time (Carr et al., 2015). Riaz et al. (2015) examined the relationship between student time spent reading an e-textbook and overall course grades, and they found no significant correlation, however, they found a significant correlation when looking at the relationship between time spent in the text and student scores on weekly quizzes. They suggest this provides a rationale for instructors to more clearly align learning outcomes with specific content from the e-textbook, ensuring students read more closely throughout the course. Mogus et al. (2012) studied the use of time logs as a variable and found – not surprisingly – a positive correlation between students' time within specific activities in a virtual learning environment and their course grades. However, Knight (2010) examined a group of undergraduates who were studying within virtual learning environments and using electronic texts. Results showed that deep, consistent interaction with learning modules produced higher grades than focused interaction at the beginning and end of learning modules, citing a need for additional research on not only the overall amount of time spent on activities but also on the amount of sustained interactivity with electronic course materials.

To date, most research in this area has focused on static computer screen e-textbooks and 'page-fidelity' texts, such as the work conducted by Rockinson-Szapkiw et al. (2013). When given the choice between print and e-textbook, students reported choosing print for familiarity, note-taking, low cost of used text, difficulty reading from a screen, and to keep the book after the course concluded; students reported choosing the e-textbook for mobility and convenience (most of these students read on a laptop, tablet, or phone). Rockinson-Szapkiw et al. (2013) found that, in contrast to Nielsen (2006), electronic and print readers reported skimming at similar rates (near 35% of the text), and nearly identical time spent reading each week (e-textbook M = 11.18, print M = 12.65). Interestingly, e-textbook users were three times more likely to take notes within the text than those who chose the print text. Relative to reading speed, print and electronic textbooks have also been compared for the effect on reading speed, revealing only a minor difference between the two (Connell et al., 2012; Kang et al., 2009).

1.5 Student perceptions

From a student perception survey, Rockinson-Szapkiw et al. (2013) reported that e-textbook readers perceived a higher level of psychomotor and affective learning than print readers and a higher level of positive attitudes toward the content or subject matter. They admit that e-textbook development is still in an early stage and they should be getting increasingly interactive and versatile. They assert that it seems most students prefer the ability to learn wherever they are – at home, on the road, at a coffee shop – and e-textbooks give them that opportunity (Rockinson-Szapkiw et al., 2013).

On the contrary, Woody et al. (2010) investigated student perception of e-textbooks, and they concluded that students prefer print textbooks over e-textbooks regardless of gender, amount of computer use, or familiarity with digital devices. They also reported no significant correlation between previous use of electronic texts and preference for their use (i.e., those who had read textbooks electronically in the past still reported a preference for print texts). Although the aforementioned finding suggests a lack of preference for e-textbooks, Henderson et al. (2016) found that 47.5% of fulltime students perceived e-textbooks as 'very useful' in their learning.

1.6 Need for study

Aside from the studies cited above there are relatively few studies (Shepperd et al., 2008; Edmondson and Ward, 2015) which evaluate student perceptions of electronic vs. print textbooks, and there is also a lack of research investigating student engagement levels when reading interactive e-textbooks. This study explored some of these holes in the research regarding electronic textbooks and their viability in higher education courses. Using a mixed-method design, the researchers sought to investigate possible correlations between student grades and three different elements of an interactive electronic textbook: total amount of time spent logged into the e-textbook, student engagement level, and percent of interactive activities accessed within the text. In addition, this study measured student perceptions of an electronic textbook compared with traditional print textbooks.

Specifically, two research questions guided the formation and implementation of this study:

a What is the nature of the relationship between course grades and student engagement within an interactive e-textbook?

b How do students perceive an interactive e-textbook, especially compared with traditional print textbooks?

This study sought to inform potential future applications of e-textbooks in classroom teaching and learning.

2 Method

2.1 Participants

This study took place within an introductory undergraduate education course at a university in the southern USA. The course was required for entrance into the teacher education program at the institution. During consecutive fall and spring semesters, 52 students were enrolled in the class, but five withdrew from the course during the study. Of the remaining 47 students, four were seniors, six were juniors, 12 were sophomores, and 25 were freshmen. Due to attrition and incomplete data, only 38 students were used as participants in this study (if a student failed to respond to all four surveys, their data were not used). Of note, only one student was male; the rest were female. As a convenience sample for the researchers, these students may not have accurately represented the overall student population of the university nor of university students generally.

2.2 Procedure

In order to examine the relationship between course grades and student use of the interactive e-textbook, three variables were identified and analysed: total amount of time spent logged into the e-textbook, student engagement level, and percent of interactive activities accessed within the text. These data were gathered by the researchers through the interactive e-textbook's built-in software. The program, MindTap, was developed and produced by Cengage ('MindTap from Cengage'). MindTap automatically gathers analytic data from each student user and aggregates the data online for the instructor to observe and analyse. Included in these data are the three variables by which student grades will be compared: time spent in the e-textbook, student engagement level, and percent of activities accessed. Engagement level within this e-text was calculated using an algorithm which included total number of user logins, number of reading activities selected, number of page navigations, number of assignment submissions, total time spent logged in, notes and highlights created, media activities launched, and searches conducted. The researchers logged into the MindTap software, observed the data, and analysed the data for each student using statistical software (SAS) to evaluate statistical correlation between the three variables and the course grade for each student. This process was repeated during the first week of each month for four consecutive months during the semester. This resulted in four snapshots of student activity within the e-textbook, allowing the researchers to see how activity varied over time.

Course grades were used as a dependent variable in this study because they are designed to be quantitative indicators of student success in learning and they are a data source that is relatable and replicable for other researchers in the field of education. Grades in this introductory education course included a combination of online quizzes (taken within MindTap), in-class writing responses, field experiences at local K–12 schools, and various formal writing assignments (research papers, K–12 observation reflections, and scholarly article critiques). The online quizzes were the only assignments factored into the course grade which utilised the e-textbook system.

In order to analyse student perceptions of this electronic textbook compared with traditional print textbooks, the researchers created a Likert-scaled survey with eight items (see Figure 1).

Figure 1 Student survey

1. I would rather use a normal printed textbook than an E-textbook with interactive activities.
2. The E-textbook for this course is convenient to use.
3. The enrichments (videos, graphics, audio, and other interactive elements) within the E-textbook enhance my learning.
4. I spend less time interacting with the electronic text in this course than I spend interacting with traditional print textbooks in other courses.
5. I am comfortable navigating materials within this E-textbook system.
6. I interact with (view, listen, click on, etc.) most enrichments within this E-textbook system.
7. When I'm logged into the E-textbook, my time is used efficiently (i.e., focused on learning).
8. I hope my future courses will use interactive E-textbooks like this one.

Note: This figure identifies the eight items included on the Likert-scaled survey administered to participants at the beginning of each month during the study.

Each item had five options for student response: strongly agree, agree, neither agree nor disagree, disagree, or strongly disagree. This survey was administered during the first week of each month for four months (in conjunction with the MindTap data analyses), giving four snapshots of student perception of the interactive e-textbook. This allowed the researchers to see how student perception may have evolved over time in the study.

3 Results

3.1 Student grades and interactivity within e-textbook

The following tables display the results of the study. Table 1 shows descriptive statistics broken down by month, including mean scores, standard deviations, and interquartile ranges (i.e., the range within the middle 50% of participant scores). These descriptive data demonstrate how performance and engagement varied or stayed the same over the course of the study.

Table 1 Summary of measures of variability by month

	Month	*Mean*	*SD*	*95% confidence interval*	
				Lower	*Upper*
Grade	1	91.72	11.45	87.95	95.48
	2	91.18	5.39	89.41	92.96
	3	91.52	5.06	89.86	93.19
	4	91.15	5.43	89.36	92.93
	Overall	91.39	7.27	90.23	92.56
Engagement	1	5.79	3.63	4.60	6.98
	2	5.89	3.54	4.73	7.06
	3	6.03	3.60	4.84	7.21
	4	6.03	3.60	4.84	7.21
	Overall	5.93	3.56	5.36	6.50
Time in course	1	145.79	146.94	97.49	194.09
	2	183.68	141.31	137.24	230.13
	3	166.58	131.21	123.45	209.71
	4	150.79	153.70	100.27	201.31
	Overall	161.71	142.87	138.81	184.61
% Activities	1	5.34	3.17	4.30	6.39
	2	7.97	3.04	6.98	8.97
	3	9.29	4.29	7.88	10.70
	4	5.61	3.20	4.55	6.66
	Overall	7.05	3.81	6.44	7.66

Table 2 Correlation between student grades and interactivity within electronic textbook

	Time		*Engagement*		*% activities*	
	r	*p*	*r*	*p*	*r*	*p*
Month 1	0.158	0.344	0.344	0.035*	0.227	0.170
Month 2	0.386	0.017*	0.082	0.626	0.084	0.616
Month 3	0.242	0.143	0.102	0.542	–0.002	0.988
Month 4	0.359	0.027*	0.199	0.231	0.412	0.010*
Overall	0.239	0.003*	0.204	0.012*	0.147	0.070

Note: *Denotes significance at $p < 0.05$.

A Pearson product-moment correlation coefficient was computed to assess the relationship between student grades and the three separate elements gathered by MindTap software: time spent in course, student engagement, and percent of activities accessed. This correlation was computed four times throughout the study. Results of these analyses can be viewed in Table 2. The following variables showed significant positive correlation with student grades during the given months: time (months 2 and 4); engagement (month 1); and percent of activities accessed (month 4). These results indicate the periods during the study when higher levels of time, engagement, or activities accessed were associated with higher student grades.

Table 3 Summary of student responses to e-textbook perception survey

	Strongly agree	*Agree*	*Neither A/D*	*Disagree*	*Strongly disagree*
Item 1					
Month 1	8	12	6	9	3
Month 2	10	12	5	9	2
Month 3	8	11	7	11	1
Month 4	9	12	9	3	5
Item 2					
Month 1	8	22	5	3	0
Month 2	3	23	9	2	1
Month 3	5	22	8	2	1
Month 4	8	23	4	3	0
Item 3					
Month 1	5	16	17	0	0
Month 2	1	16	15	3	3
Month 3	1	12	19	5	1
Month 4	4	12	12	9	1
Item 4					
Month 1	3	7	14	12	2
Month 2	5	11	10	11	1
Month 3	2	15	9	9	3
Month 4	8	10	7	12	1
Item 5					
Month 1	7	23	3	5	0
Month 2	4	22	6	6	0
Month 3	7	23	5	3	0
Month 4	11	18	5	4	0
Item 6					
Month 1	3	18	5	11	1
Month 2	1	11	12	12	2
Month 3	2	12	9	12	3
Month 4	5	8	6	15	4
Item 7					
Month 1	6	21	3	8	0
Month 2	5	20	4	6	3
Month 3	8	14	11	4	1
Month 4	9	18	7	2	2
Item 8					
Month 1	3	9	15	8	3
Month 2	2	7	13	13	3
Month 3	3	12	10	12	1
Month 4	7	9	14	6	2

Note: Each cell shows the number of participants who selected that particular response.

3.2 Student perceptions of e-textbook

The researchers used Google Forms to organise and disseminate the Likert survey four times. The same eight items were used each time in order to evaluate how student perceptions of the e-textbook changed (or stayed the same) over the course of the study. Survey results for each question appear in Table 3. All data, including complete e-textbook analytics and statistical analyses, can be provided upon request.

4 Discussions

The purpose of this study was to investigate possible correlations between student grades and three different elements of an interactive electronic textbook: total amount of time spent logged into the e-textbook, student engagement level, and percent of interactive activities accessed within the text. These analytic data were collected using MindTap software and analysed using SAS. In addition, this study identified student perceptions of an electronic textbook using a Likert-style survey administered online through Google Forms. The data help to inform potential future implementation of interactive e-textbooks in various classroom settings.

4.1 Student grades and interactivity within the e-textbook

4.1.1 Grades and time

An analysis of the e-textbook analytics (see Table 2 for all data discussed in this section) revealed a significant positive correlation in overall time spent within the e-textbook and overall course grades (all correlations calculated at $\alpha = 0.05$). These results corroborate the assertion that increased time spent using e-textbooks is associated with higher course grades (Mogus et al., 2012).

When looking at month 1 in isolation, the relationship was not statistically significant, but course grades during the first few weeks of the semester may be less accurate representations of proficiency or content mastery than those that occurred later in the semester. Month 3 also showed no significant relationship; this may be because, during this month, students were spending most of their class time participating in field observations, and the e-textbook was not the central focus. This result supports the finding of Knight (2010) who asserted that deep, consistent interaction with learning modules produce higher grades.

4.1.2 Grades and engagement

An analysis of the e-textbook data also revealed a significant positive correlation in overall engagement with the e-textbook and overall course grades. This finding aligns with the idea that interactive e-textbooks may increase student engagement with the text (Maynard and Cheyne, 2005), which is an integral facet of active learning. As stated earlier, engagement levels were calculated using a complex algorithm that included several factors, so it is difficult to portray exactly what engagement looked like in this study, but the overall significance lends support for more exploration into interactive e-textbooks and the opportunities they provide for students.

4.1.3 Grades and activities accessed

Results showed that the correlation between course grades and percent of e-textbook activities accessed was not statistically significant when looking at the course as a whole; however, month 4 – when observed in isolation – showed a significant positive correlation ($p = 0.010$). This is worth noting because this was the month students were using the e-textbook most heavily, in preparation for their final course presentations. Perhaps the increased emphasis placed on studying the text and preparing for final presentations motivated students to become more active within the e-textbook, accessing and interacting with supplementary videos and activities. If students could sustain that type of interaction with electronic materials throughout the course, their overall grades might reflect the deep, consistent effort recommended by Knight (2010).

The significant positive correlation between grades and time, as well as grades and engagement, gives reason for educators to examine the potential for e-textbooks in their courses. If electronic texts are of high quality (e.g., accurate, relevant, and current) and include elements that provide opportunity for more student engagement (e.g., videos, links, and learning activities) student grades may improve.

4.2 Student perceptions of e-textbook

An analysis of student perceptions regarding the e-textbook used in this course offer several points of discussion (see Table 3 for all data in this section). The data revealed that the majority of participants (21 of 38) still preferred print textbooks over e-textbooks, with nearly a quarter of the class (nine of 38) undecided (item 1). By the end of the study, more than 80% of students (31 of 38) felt like the e-textbook was convenient to use (item 2). Naturally, students became more comfortable navigating course materials as the study progressed; by the end of the study, 29 of 38 reported feeling comfortable navigating the electronic course materials (item 5). These findings support the existing research (Hoseth and McLure, 2012; Henderson et al., 2016) which cite convenience and student usefulness as benefits of e-textbook use.

Data also showed a shift from the perception that the digital enrichments enhanced student learning to the perception that they did not really enhance learning (item 3). This departs from Maynard and Cheyne's (2005) assertion that e-textbook interactivity increases student learning. Educators considering interactive e-textbooks would want to investigate the digital enrichments (videos, links, activities) in close detail, ensuring they are of good quality and relevant for student learning.

Responses to item 4 showed an increasing perception that students spent less time within the e-textbook than they typically would have spent within a print textbook (18 of 38 participants agreed with this item by the end of the study). Perhaps students skimmed electronic content instead of reading deeply, as was posited by Morkes and Nielsen (1997). If students felt a consistent need to engage deeply with the content, they may have been more motivated to spend additional time within the e-textbook. This resonates with the recommendation by Riaz et al. (2015) that instructors align course learning outcomes with mastery of the e-textbook content. Additional research could explore this finding by assessing quality of time spent using e-textbooks instead of just focusing on quantity. Respondents largely (27 of 38 students) felt their time was well-spent within the e-textbook (item 7), and results were fairly split when asked whether they would want to use e-textbooks like this one in future courses: 16 agreed, eight disagreed, and 14 were undecided (item 8).

Overall results from this Likert survey do not offer a clear endorsement of the interactive electronic textbook used in this introductory education course, but they also do not reveal any reasons to discontinue its use. As students and instructors become more familiar with the tools and resources provided within the MindTap software, beliefs regarding the effectiveness and usefulness of the e-textbook may change. The lack of a consistently strong correlation between e-textbook interaction and course grades may reveal a need to evaluate the activities required of students within the e-text, and also suggest a reconsideration of how learning is assessed in the course.

4.3 Limitations and recommendations

This study represented data from two sections of an introductory course, and there were a limited number of participants (n = 38) due to attrition and incomplete data. This is a limitation that may have weakened the validity of the results. Another factor that influenced results was that students had the option to purchase a loose-leaf printed version of the text in addition to the electronic textbook. While students were required to log into the textbook to take quizzes and watch video clips, they had the option to read the chapters using the print version if desired. This impacted the time spent within the e-textbook and the other analytics that MindTap gathered. Finally, the course grade was affected in part by several elements that were not connected to the electronic text. For example, time spent observing K–12 students in a classroom setting, with an accompanying writing task, accounted for a decent portion of the course grade. This assessment did not have any connection to the electronic content within MindTap, which may have reduced the chance for a strong correlation between course grades and e-textbook activity.

It is recommended that this study be replicated in various content areas within higher education institutions and using various electronic textbook software. The principles and goals behind this study (correlation between grades and e-textbook involvement, student perceptions about e-textbooks) can transfer to any course in which an e-textbook is a viable option for course content. The study could also be extended across multiple semesters to see if results change as instructors become more comfortable with digital resources provided within the e-textbook.

While the feature was available with this e-textbook, digital annotation was not the focus of this study. Such note-taking features could increase engagement and student learning, so additional research could focus on those elements. Surveys could also be broadened to evaluate the type of devices students use to access the text, the amount of note-taking or annotating happening within the text, or the types of distractions student face when reading digital texts vs. print texts. Additionally, this study could be adapted to focus on student autonomy or self-regulation. Research into some of these other spaces may further illuminate the value of or problems associated with a shift towards interactive electronic textbooks in higher education.

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Multimodality and Accessibility - Workshop Day 3

Introduction

Commercial textbooks tend to be heavily illustrated, even though these illustrations make the books more expensive. Clearly, for-profit textbook publishers have determined that the return on illustrations is greater than the investment. But when you make the decision to design or choose an OER, your rationale for illustrations should be practical rather than financial. Fundamental questions about the purpose of illustrations need to be revisited. For instance, do teachers and students want illustrations in learning materials because they make them more pedagogically effective or because they make them more visually appealing? In either case, the content of illustrations is not directly accessible to people who cannot see them. To make OERs that are accessible to the widest possible audience, including people who use screen readers and other assistive technologies, designers may need to include audio and/or video in addition to text and/or images. The readings for the third day of the workshop, a 2016 document by Dave Gunn and a 2019 chapter by Richard Mayer, suggest approaches and rationales for designing or choosing accessible multimedia formats and interfaces.

Gunn, D. (2016). *Accessible eBook guidelines for self-publishing authors*. Accessible Books Consortium. https://www.accessiblebooksconsortium.org/export/abc/abc_ebook_guidelines_for_self-publishing_authors.pdf

Gunn (2016) discusses different types of disabilities and various eBook formats that you may want to consider when designing or choosing accessible electronic textbooks. The article is intended for self-publishers, so it also includes a section on how to construct accessible source documents that will later be converted to one or more eBook formats.

As you read this document, please

1. Think about what updates to its coverage of disabilities and formats you could suggest and share with the class
2. Think about any disability-related policies in your region that you would need to be aware of when developing an OER
3. Add at least one discussion question to our class Google doc

Mayer, R. (2019). How multimedia can improve learning and instruction. In Dunlosky, J. & Rawson, K. (Eds.), *The Cambridge handbook of cognition and education* (Cambridge

Handbooks in Psychology, pp. 460-479). Cambridge University Press. https://doi.org/10.1017/9781108235631.019

Mayer (2019) summarizes 12 principles for multimedia learning materials in both print and electronic formats and goes over the research evidence for each principle as well as its applicability to different students, materials, and subject matters. The 12 principles derive from his "cognitive theory of multimedia learning," which holds that when a concept is presented to learners in verbal *and* visual modalities, learners cognitively construct verbal *and* pictorial representations of the concept that are then integrated with each other and with related background knowledge to form a mental encoding of the concept that is more robust and retrievable than it would have been if the concept had been presented in a single modality. As you read this chapter, please

1. Think about how the textbooks and other learning materials that you use might do a better job of incorporating these principles.
2. Add at least one discussion question to our class Google doc

Accessible Books Consortium

Bringing books to persons with print disabilities

INTERNATIONAL AUTHORS FORUM

Accessible eBook Guidelines for Self-Publishing Authors

Written by Dave Gunn

Published by the Accessible Books Consortium, in conjunction with the International Authors Forum.

January 2016

Hosted by WIPO

Foreword

No matter if you are thinking of self-publishing your first book or you are a seasoned author with existing publications, this guide is designed for you. It will introduce you to the ways people with print disabilities like sight loss, dyslexia or a physically limiting disability can read using eBook technologies. It will highlight some of the potential challenges and walk you through the steps you can take to make your next publication more accessible to this global audience of people with print disabilities. An estimated one billion people worldwide have some form of disability, many of whom will be unable to read conventional publications. There are so many people in this group that you probably have friends or family members who are unable or struggle to read conventional print. More importantly, as globally people are living longer, the ageing population is predicted to significantly increase the number of people with print disabilities. By considering accessibility in the self-publication of your eBook, you not only help to create a more equal world for people with print disabilities but you also enable a much wider population to enjoy the result of your work.

In this guide you will:

- Be introduced to the key terms and concepts in eBook accessibility
- Understand how people with print disabilities can read eBooks
- Discover how to create a manuscript which supports accessibility
- Learn about accessibility in the major eBook formats
- Explore how the primary self-publishing retailers support accessibility
- Investigate some of the challenges in accessible eBook publishing

Towards the end of this guide a checklist is provided for you to work through the key accessibility considerations for your publication, reviewing the key points made throughout the document.

Statement from the Alliance of Independent Authors:

The Alliance of Independent Authors (ALLi) is delighted to support the International Authors Forum (IAF) and the World Intellectual Property Organization's (WIPO) Accessible Books Consortium (ABC) initiative, raising awareness of the very important issue of eBook accessibility for persons with print disabilities - far too easily overlooked or misunderstood by indie authors/author publishers focusing on the mainstream market. These clear and practical recommendations will make them realise how easy it would be to make their eBooks more accessible, greatly increasing the range of books available in appropriate formats for people unable to read standard print and, at the same time, boosting their potential readership substantially. It is a win-win scenario.

Disclaimer

All reasonable precautions have been taken to verify the information contained in this publication. However, the published material is being distributed without warranty of any kind, either expressed or implied. The responsibility for the interpretation and use of the material lies with the reader. In no event shall the author, the Accessible Books Consortium or the International Authors Forum be held liable for any consequences of its use.

Table of contents

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1. What is eBook accessibility?

Anyone authoring a book would like it to be read and enjoyed by the widest possible audience. For many people this is simply a matter of awareness and personal preferences. However, people with print disabilities have historically been exposed to a much more restricted catalogue of titles. Just a few years ago, fewer than 5% of publications in the western world were available in an accessible format like braille, large print or audio, and fewer still were available in a more flexible digital format. At the same time, in developing countries, it was estimated that fewer than 1% of publications were available in any accessible formats, resulting in a significant barrier to education and social inclusion.

EBook technologies have opened up an array of new opportunities for people with print disabilities to gain equal access to the same publications as their peers without delay and with no dependence on the limited resources of charitable organisations. EBooks have the potential to be enjoyed by everyone irrespective of disability and this can often be achieved very simply.

Key terms in the process

Because eBooks are still a relatively new technology for many people, the terms used in the publication process can become confusing, especially those terms which can be used interchangeably based on context. For clarity, the following terms will be used throughout this document.

- Author Publisher: the person who created the original Work which they would like to publish, and also in this process the person who has a formal relationship with an eBook Retailer to make the book available.

- eBook Retailer: the technology company which establishes a formal relationship with the Author Publisher, accepting their Work in a digital form, automatically converting it and making it available through their eBook shop.
- Intermediaries: an optional third-party organisation which offers to work on behalf of an Author to process and submit their Work to an eBook Retailer, managing the technology and assisting with establishing the relationship.
- Reading System: because the term "eBook reader" can confusingly refer to both a user and the piece of technology rendering an eBook, the industry has adopted the term Reading System to reference a tool used to access and navigate the eBook. This could be a conventional piece of software for a desktop computer, an App for a smart phone or tablet, or a dedicated piece of technology. All the major Retailers have their own dedicated Reading Systems which have to be used to access their eBooks.
- User: the customer of the Retailer who buys the eBook and reads it on their Reading System of choice. In the context of this document, this user is a person with a print disability and the Reading System may need to have special qualities for the eBook to be accessible.

The Glossary of terms towards the end of this document offers a reference resource and additional descriptions for phrases used throughout this document.

2. How eBook accessibility works and for whom

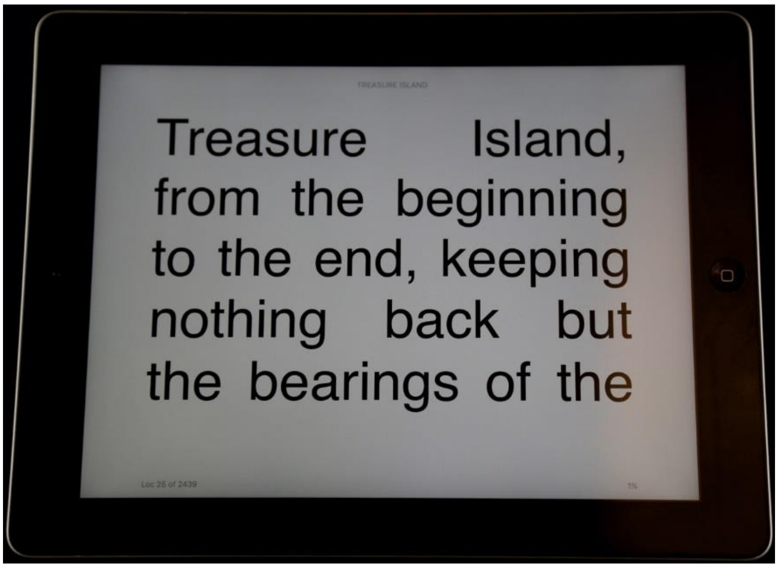
The essence of eBook accessibility relates to supporting flexible ways for people to engage in the eBook content based on their personal needs. The adage of "no one size fits all" is particularly true of people with print disabilities accessing eBooks or any reading material and one of the strengths of eBook technologies is to allow users to quickly and easily customise the way the content is presented to suit their requirements.

Some of these customisations come by default in all reading systems and some are more specialist requiring additional equipment to be achieved. Developments in portable mainstream devices like tablets and phones have resulted in affordable equipment capable of supporting a diverse range specialist needs. If you have a modern smart phone or tablet, you may be surprised that the device you regularly use can offer life changing access to eBooks for people with a variety of print disabilities.

Visual Impairment

For individuals with low vision, control over the way text is presented is essential. Many people with a visual impairment may simply need to enlarge the size of the text before they can read it and, in some cases, this can mean increasing the scale so only one or two words fit on the screen at a time. In conjunction with text size, some people with a visual impairment also benefit from being able to change the typeface and, while there is limited evidence to indicate a single preferential typeface over another, research does suggest people with a visual impairment find reading much easier with a typeface of their choice. People with certain eye conditions also benefit from increasing the contrast of the text from the background, with yellow and black being a common colour combination used interchangeably for text and background colours. It is not uncommon for the reading requirements of people with low vision to change throughout the day, typically needing to increase the text size later in the day as their eyes get tired.

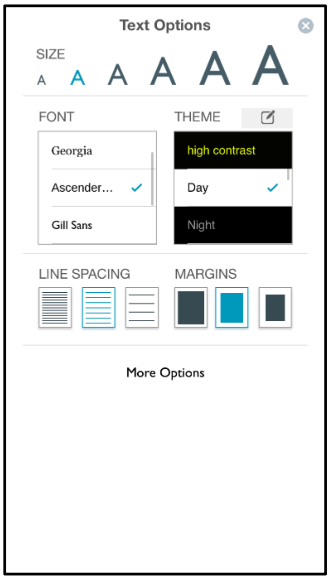
The image below is from an Apple iPad screen showing the Amazon Kindle App at maximum size text, which equates to approximately 54pt size text.

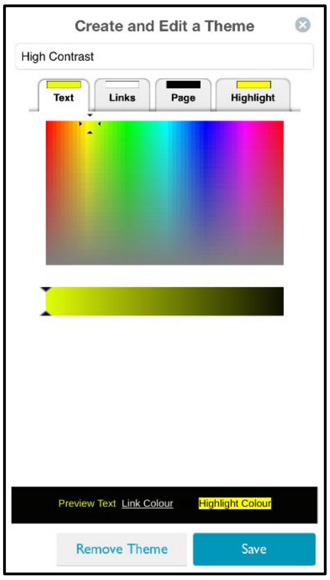


Dyslexia

This category of users is the largest, with current estimates of around 1 in 10 people having some form of dyslexia, but it is also the most diverse and reading requirements within this group vary significantly. Generally considered a learning difficulty rather than a disability, dyslexia is characterised by trouble reading, and can also include difficulties spelling and writing. Users with dyslexia benefit from customising the typeface, text size, controlling the space between words, line spacing, as well as reducing the contrast between the text and background and changing their colours. Some people with dyslexia also benefit from audio versions of the text, sometimes synchronised with highlighting of the text itself to help individuals follow along as the text is voiced.

The images below from the Nook Reading System on iOS show the presentation customisation settings offering control over text size, typeface, layout and colour.

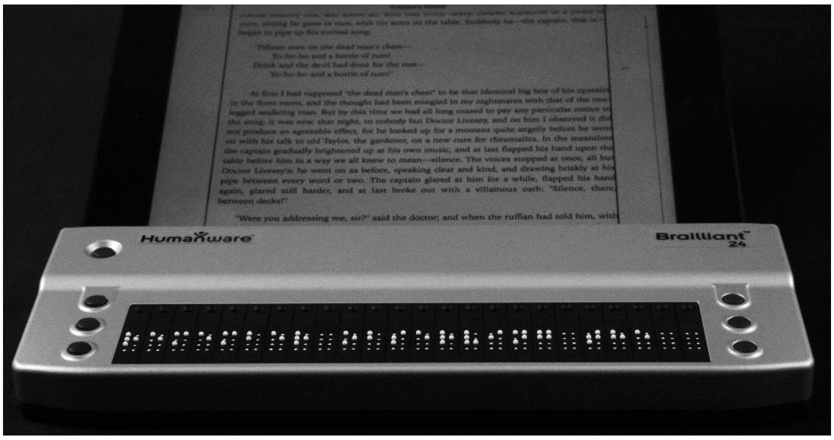




Blindness

For people who have no functional vision, the text of the book needs to be rendered in an alternative format. Audio is probably the most common solution and many modern touchscreen phones and tablets are capable of switching to a gesture based user interface and generating natural sounding synthetic speech. The gesture controls can then be used to read and control an eBook. The same technology can also be used to convert text into the raised dot format braille. A specialist electronic braille display can be connected wirelessly, containing a series of pins which raise and lower to create letters and words in the tactile format. Additional buttons on the device can also be used to navigate the document.

The image below shows a portable refreshable braille display, which is connected wirelessly to an Apple iPad mini to show in braille exactly what is displayed on the screen in Apple iBooks.



Physical disabilities

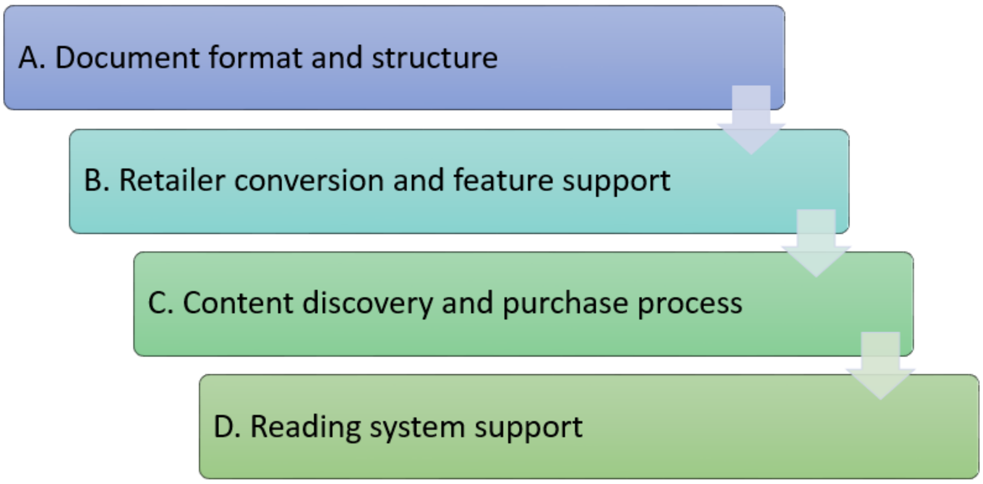
People with physical disabilities are also able to enjoy accessing text through eBooks when they might otherwise be unable to hold a book or eBook reading device or may not have the fine motor skills to turn a page or push buttons on a conventional device. Computers, tablets and phones can be controlled through a variety of customisable physical switches, gesture based controls or even eye tracking allowing someone with limited mobility to navigate through an eBook.

3. Factors which influence eBook accessibility

EBook accessibility is a fairly complex topic, with many opportunities at each stage in the process for best intentions to go awry before an accessible publication can be enjoyed by an individual who would otherwise be unable to access a conventional publication.

The area is so multifaceted that this document will not attempt to cover everything but it will highlight the key topics for authors to make decisions and further enquiries with the retailers. While many other parties have roles to play in ensuring a publication reaches and can be accessed by an individual with disabilities, the primary responsibility rests with the author. Without due consideration and appropriate action, the process of making a publication accessible is unlikely to succeed.

The chart below, which is described in the following paragraph, summarises the stages in the self-publishing process which have accessibility implications.



The outcome of an eBook being accessible to an individual with print disabilities relies on a number factors including:

A. A well-prepared source document which is appropriately formatted and well-constructed to support accessibility features. This is typically a word processed document but may be converted to an eBook format.

B. Quality ingestion of the content by a Retailer to create a user-ready eBook which supports accessibility and preserves the features of the source manuscript. This can include conversion to an eBook format or simply processing of a submitted eBook.

C. An accessible retail environment where users can find or choose a book and then complete a purchase or loan process to obtain the eBook they have selected in an appropriate format.

D. A Reading System (hardware, software or App) which supports accessibility, and specifically the accessibility requirements of the user. This might also include the option for specialist third party hardware or software to enable access (like a braille display or switch controls).

Clearly, not all of these factors can be affected by an author looking to self-publish. However, the decisions made at the start of the publication process can make the difference between an eBook which cannot be read by people with print disabilities and one which has the potential to be fully accessible and enjoyed by everyone.

4. Constructing an accessible source document

The optimum route to an accessible eBook starts with the creation of a source text which is well structured and contains the appropriate information to facilitate accessibility. In most cases, this is actually a fairly straightforward process which can be achieved in all of the common word processing applications. In addition, this process is recommended by most of the companies supporting and offering self-publishing, including the retailers.

This is because the retailers perform an automated conversion of the submitted manuscript to an eBook format and even manuscripts submitted in an eBook format will be automatically analysed and modified to work within their system.

Conversion of any electronic document between formats will at best only preserve the content and features of the original document but, in many cases, it is a subtractive process with some information being lost in the transition. In most cases, this information is not essential to the resulting eBook. The process is very rarely additive, especially when it comes to accessibility in self-published eBooks, since the process is fully automated, the end result being that your publication will only be as accessible as you choose to make it through the construction of an accessible source manuscript.

Applying Styles

Document structure is achieved by formatting text using styles instead of character formatting. One example is, when adding a chapter title, it is possible to increase the font size and make it bold but this does not inform the document or the user that this is a chapter title. The more accessible and usable solution is to apply a Styled Heading Level, which enables the generation of an automated table of contents and, more importantly, allows people to navigate the document to that chapter and, once there, be able to identify their location.

Styled headings are easy to apply and come with some very simple rules: always apply styles consistently – so, if you use Heading Level 1 for a chapter heading, all chapter headings should use Heading Level 1. Heading levels should be applied in sequential order – for example, Heading 1 for chapter titles, Heading 2 for sub-section titles, and Heading 3 for the next section within that.

Additional styles should be used for quotes, captions and even customised styles can be created and, although only heading level styles are essential for accessibility, you will benefit from consistent layout and design by using styles throughout your document.

Character formatting

When it comes to document formatting, many people are familiar with the menu options on their word processor which allow changes to font size, typeface, colour or to make the text bold, underlined or italicised. This character formatting can make the document more visually appealing. However, it is important to be aware that it typically conveys little or no information in an accessible document and can, in some cases, hamper accessibility.

When large expanses of text are formatted to be bold or italics, it can be difficult for some users, like people with dyslexia or low vision, to read. So when character formatting is used, it should be applied sparingly. Because the formatting information is typically not conveyed in formats like audio and braille, it should not be used in isolation to convey information.

Image accessibility

All of the eBook formats support the option to include images and, while many readers will benefit from the inclusion of graphics, they can prove challenging from an accessibility perspective.

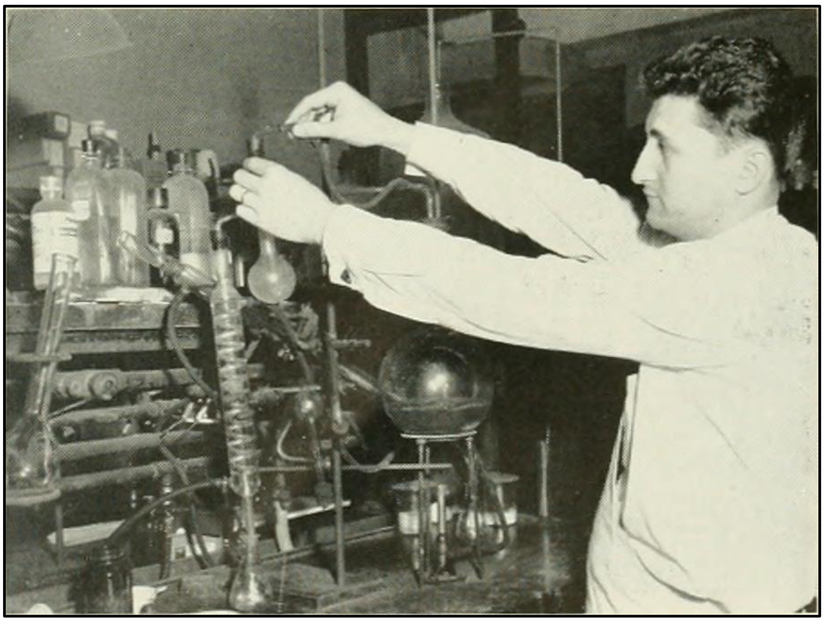
When adding an image to an eBook, it is important to remember that it will be displayed differently on the range of different reading systems people can use to read your eBook. The size of the screen can vary significantly making a potentially clear image on a large screen much more challenging to read on a smaller device. Also e-Ink devices capable only of greyscale will lose any colour information in your image.

EBooks which are rendered as audio or braille will not be able to include any images but can instead incorporate a description of the image. Image descriptions can be added to an image as a caption or inserted into the image metadata as an alternative textual description known as alt text. Alt text can be inserted when the image is added to the document or at any time through the image properties.

Some word processing applications allow both a title and a description field for image alt text, whereas other applications have just a single field. Depending on the word processing application and the chosen retailer, the content of both, one or neither of the alt text fields may be retained. For the best results, a single field should be used consistently and the images should be checked throughout the conversion process to ensure that the alt text has been preserved and not placed below the image or completely removed.

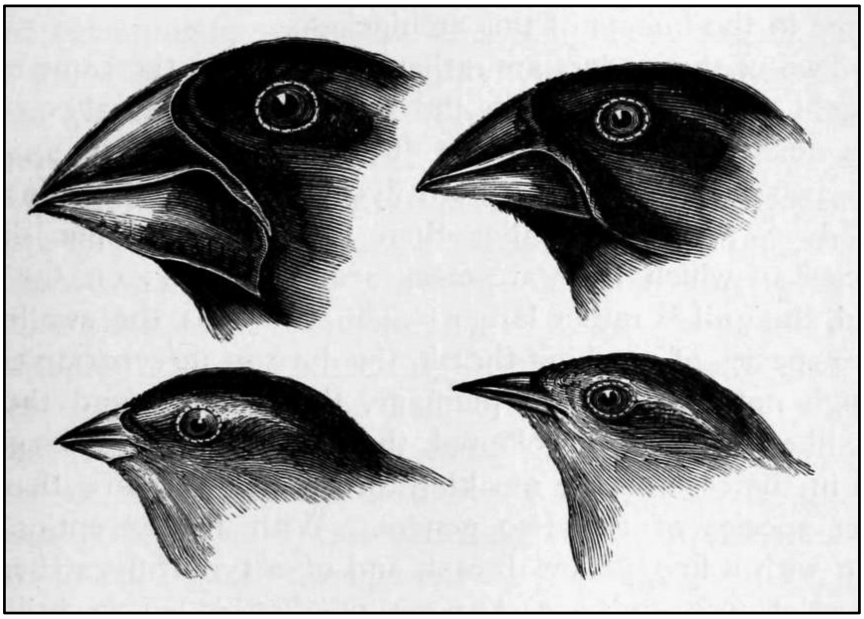
Not all images need to be made accessible and, as a simple guide, only those images which convey key information not already described should have an alternative description. This means any purely decorative images do not need to be described and, if an image is adequately described in a caption, it does not need to be repeated as alt text. Where an image is displaying information where people might reasonably be expected to draw a conclusion, it is best to include that conclusion in the alt text. For example, “Chart of coffee sales for 2015 showing a gradual increase in sales throughout the year” or “map of an island with a red X in the south west near a church”.

Because the alt text should be written to reflect the context of its use, images do not typically have a single description that will work in all settings, as shown in the following examples.



The chemistry example above could have any of the following alt text descriptions:

- Photograph showing 1950 chemistry safety procedure of working with extended arms.
- Photograph of a chemist working with laboratory equipment.
- Photograph showing chemistry in police testing for alcohol in 1957.



The bird illustration image above could have any of the following alt text descriptions:

- Four hand drawn illustrations of bird heads.
- Illustrations of Finch heads from the Galapagos Archipelago by Charles Darwin.
- Drawings showing the differences in beak size of Finches from the Galapagos Islands.

Based on the context of the surrounding text, any of the descriptions above would be valid. When writing your alternative description consider how it fits within the surrounding text and what information is conveyed through the image alone. If you leave a learning objective for people to conclude from viewing the image, you will need to convey that succinctly in the alt text. Where an image is added to reinforce the message, the full message does not need to be repeated and a brief description of the image title can be added instead.

Currently, even though all of the eBook formats support the inclusion of alt text, not all eBook reading systems support their use which means your descriptions may not be available to the reader.

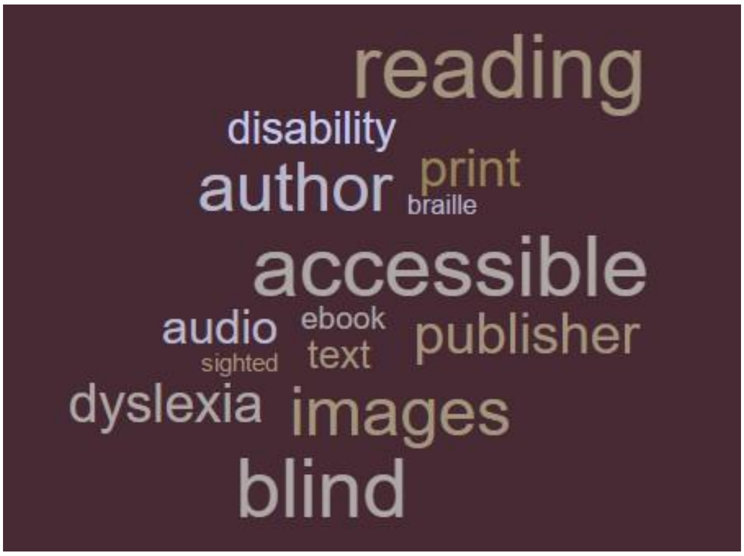
Alt text is still the most appropriate solution for image descriptions but, to guarantee the availability of the description to users accessing your eBook in an accessible format, it is currently best to ensure your learning objectives are encompassed within the text of your publication.

Links to further advice and examples on the content of image descriptions can be found in the Other Resources section of this guide.

Text as graphics should be avoided

One of the biggest challenges in text accessibility is when creators highlight words by designing them into an image. This is very common in social media, producing an image with a few words and a background image or a word cloud of key points.

The image below demonstrates the bad practice of a word cloud which will not produce any accessible text.



In eBooks this can also include design features like dropped capitals at the start of a chapter. Wherever possible, text should be preserved as text throughout your document and, where it is necessary as an image, necessary steps should be taken to make that image accessible.

Avoid using tables

Information laid out in a tabular form can be a very effective way to visually show the relationships between data elements and enable detailed analysis of the content. In an eBook, tables can present serious issues, especially when the text size is enlarged or displayed on the small screen of a mobile device and the entire table does not fit within a single page. In addition, some methods of navigating tables with access technology make it difficult to relate a specific cell to the row or column headings, which makes using a table a complex and incredibly challenging memory game. To make tabular data as accessible as possible, try to keep any tables small, perhaps using multiple tables instead of a single large one. Where possible, you might want to consider describing the relationship and trends within the data, making navigation of the table less critical.

5. Introduction to eBook formats and accessibility support

The notion of packaging books electronically for delivery has been with us for a while and, over 10 years ago, many companies wanted to develop their own solution as the format of choice with more than 20 format options available. Over time, the number of options has reduced to just 2 main formats: EPUB and Kindle. It is important to note that, simply because an eBook format has the capability of supporting accessibility, it does not automatically make content accessible. Outside of the mainstream eBook formats for self-publishing, there remain a few alternatives which are also highlighted.

EPUB

EPUB is the leading format in the digital publishing sector and was developed as an open standard by the industry for anyone to use. It is the format of choice for the majority of eBook publishers, reading systems and eBook retailers. EPUB3, the latest version of the standard, was developed to meet the needs of modern mainstream publishing but also had accessibility in mind from the outset. Throughout the development process, consideration was given to how all the features could be made accessible to people with print disabilities. The result is an eBook format which has the potential to contain and deliver complex content in a completely accessible way and, as a result, the format has been endorsed by publishing and disability organisations globally as the best way to publish.

Kindle

The Kindle format or, more accurately, collection of formats, are based on a closed standard from Amazon and the Amazon Kindle eBook environment is the only retailer to use these formats. Because the specification for the format is not made public, it is not as simple to assess for accessibility. However, it is clear that improvements in accessibility have been made over time.

A well-constructed conventional book which is text driven has the potential to be fully accessible in the Kindle format. The format also has the potential to support image accessibility, but the Kindle reading systems do not currently support the information (alt text) required to make images accessible.

Adobe PDF

The PDF format was developed to preserve the visual layout of documents across devices. PDF as a format has changed over time and now PDF documents can support accessibility. It is important to note that creation of an accessible PDF document does not happen automatically in any conversion or export function, and the conversion to other accessible formats remains challenging. As a result, PDF is not recommended as an intermediary format for submission to eBook retailers.

EBooks as dedicated Apps

It is possible to develop an eBook into a dedicated App for sale on a mobile platform. All of the major platforms (e.g., iOS, Android) support accessibility and it is possible to create a fully accessible App to run on these platforms. Guidelines on accessible App development are available from all the platforms and care should be taken to ensure any App developer or service offering conversion follows the recommended guidelines to produce an App of the required accessibility.

6. Accessibility in self-publishing retailers

The level of accessibility support varies significantly in different self-publishing channels, with most of the major companies having made some considerations towards accessibility support but not necessarily across all of their platforms or to meet the requirements of all the print disability groups. The number of global routes to self-publishing makes it challenging to provide a comprehensive review of all the available options. Instead we can look at some of the larger companies to explore the options and the complexity which surrounds them.

It is important to note that the eBook sector is highly competitive, with regular updates issued to improve the conversion and delivery of publications, as well changes to improve the reading systems people use. All the self-publishing channels highlighted have additional information on their websites to describe the features they support and the recommended format for your manuscript. It is recommended that authors search for the latest website updates and then contact the relevant companies to ask any specific questions they may have.

This guidance does not cover the user experience of finding and purchasing a title for each retailer, primarily because this can vary significantly depending on the requirements of the individual, the technology they use (specialist or otherwise), and even their geographic region. If you are interested, you may want to ask your preferred retailer about the accessibility of their content discovery and purchase experience.

Amazon Kindle Direct Publishing

https://kdp.amazon.com/

EBook format and features

EBooks published through the Amazon Kindle service use the Kindle eBook format. Behind the scenes technically, there are several Kindle formats which offer a variety of features, with periodic updates to the format to add new features and ensure the documents can be read across their portfolio of Reading Systems.

KF8 is the latest generation of Kindle format and recent updates have enabled support for embedded video, audio and animations. The Kindle Direct Publishing programme can accept these highly technical eBooks. However, it is primarily focused on conventional novels and the guidance available on the site is focused on these traditional and more straightforward publications.

Kindle is capable of supporting basic accessibility for conventional novels, primarily related to the presentation and navigation of structured text. Image accessibility, and the accessibility of more complex content like mathematical equations, video or interactivity are not currently supported.

Accessibility advice

Amazon does not offer any specific accessibility advice to authors or eBook creators. The general guidance offered by Kindle recommends that manuscripts should be kept as simple as possible, using only very basic formatting, all of which is in line with accessibility recommendations.

Reading System accessibility

Amazon has done a considerable amount of work to make its reading systems accessible to people with print disabilities, with options throughout their range supporting the needs of people who read through braille, audio, enlarged text or require customised colours. With a diverse range of reading options available on desktop computers through to dedicated e-Ink displays like the Kindle

Paperwhite, limitations on devices prevent the full range from supporting all accessibility features (e.g., you will not get colour customisation options on a black and white e-Ink display) but, where practical, accommodations appear to have been made. Of particular note are the Kindle Fire and Kindle iOS Apps, both of which have extensive support for accessibility.

Kindle supports (in at least one Reading System):

- Audio
- Braille
- Colour customisation (limited)
- Layout and typeface customisation

Issues and workarounds

At present Kindle does not support image accessibility through alternate text descriptions (alt text), and no guidance is offered on the topic. There are, however, signs in some of their publishing tools that this feature may be supported in the future. To make the most accessible Kindle eBook, consider using captions below any images to describe the image content and convey any learning objectives.

Apple iBooks

http://www.apple.com/itunes/working-itunes/sell-content/books/

EBook format and features

iBooks uses the EPUB format to deliver and display eBooks and support for the various features of EPUB is quite extensive, encompassing functionality for technical publications, interactive elements, multimedia resources and early years literacy. There are, however, limitations for authors who do not use Apple computers. All manuscripts need to be submitted through the free iTunes Producer application for Apple computers, which is available to Mac users after signing a contract through iTunes Connect. Files can then be submitted in iBooks Author format (.iBooks), or as a valid EPUB 3 eBook. iBooks Author is also a free application for Apple computers.

Accessibility advice

Apple has been at the forefront of adopting accessibility features in the EPUB format and has supported those features in their eBook designing tool iBooks Author, actively enabling accessible output from all the default options.

Third party guidance is available to support people creating accessible eBooks using iBooks Author and more general accessibility advice is available from Apple.

Reading system accessibility

Apple iBooks is generally considered to be one of the most accessible reading environments, with iBooks on the iPhone and iPad being very accessible. The presentation options on iBooks are generally much more limited than other reading systems and may be restricting for people who need to read using a specific colour combination or certain typeface to read.

The range of Reading Systems is also much more limited than all of the eBook Retailers, with the iBooks Reading System only available for Apple computers and devices (iPod Touch, iPhone and iPad).

iBooks supports (in at least one Reading System):

- Audio
- Braille
- Colour customisation (limited)
- Layout and typeface customisation (limited)

Issues and workarounds

Fixed layout publications have become popular in iBooks to control and preserve the layout throughout the document. Creating eBooks with fixed layout will severely limit the accessibility of your publication for people who need to enlarge the text or change the presentation options and, as a result, this feature should be avoided.

Many third party plug-ins (widgets) are available for iBooks Author to enhance and add options for complex content. However, many of these developments will not have considered accessibility and could, as a result, make your publication less accessible. It is therefore recommended that authors ask third party developers about the accessibility of the output from their widgets or limit their widget use to the default options.

Barnes & Noble Nook Press

https://www.nookpress.com/ebooks

EBook formats and features

Nook uses the EPUB format to create and deliver their eBooks, although no prior experience of the format is required as manuscripts can be uploaded in all the common word processing formats and then edited and proofed in their online tools. EPUB supported by Nook offers all the primary features to enable a fully accessible novel, with more advanced features available for people creating and submitting a publication-ready EPUB3 file.

Accessibility advice

No specific advice on eBook accessibility for authors is offered by Nook, although they do offer guidance on manuscript formatting which is in line with accessibility good practices.

Reading System accessibility

The development team at Nook have clearly invested time in exploring the accessibility options for their Reading Systems and implementing the features where possible. As a result, Nook offer some of the most complete reading experiences for people with print disabilities, especially on mainstream mobile devices (iOS and Android) which are a beacon of good practice. Of particular note is the extensive range of colour customisation options, allowing people to fully customise the presentation of the eBook on screen, and the on-device tutorial which is automatically provided to people using speech technology when accessing for the first time.

Nook supports (in at least one Reading System):

- Audio
- Braille
- Colour customisation
- Layout and typeface customisation

Issues and workarounds

The Nook Press online manuscript editor does not currently support alt text for images, requiring images to have descriptive captions for accessibility instead.

Kobo Writing Life

https://www.kobo.com/writinglife

EBook formats and features

Kobo also uses the EPUB format to deliver its eBooks and supports a range of features that come with the format, although the Kobo publications are focused primarily around conventional eBooks with structured text and images. Manuscripts can be submitted in the common word processor formats, as well as EPUB and MOBI files.

Accessibility advice

Kobo offers no accessibility advice and only limited guidance on document preparation and layout, although the information offered on formatting is in line with accessibility good practices.

Reading system accessibility

Kobo offers a range of reading systems across all the common platforms, as well as dedicated e-Ink and colour tablet hardware. While the Kobo range does support a good range of text sizes and some presentation customisation options, overall the Kobo Reading Systems have limited accessibility support, with no support for reading through audio or through connected braille displays.

Kobo supports (in at least one Reading System):

- Colour customisation
- Layout and typeface customisation

Issues and workarounds

Because the eBook format supported by Kobo is fully featured and any accessibility challenges sit with the Reading Systems, it is recommended that manuscripts submitted to Kobo continue to follow the best practice recommendations and the no workarounds should be implemented. This allows the most accessible eBooks to become available when Kobo does make its Reading Systems more accessible.

7. Accessibility challenges

The possibilities offered in modern eBook publishing are truly expansive, with support for a wide variety of content beyond conventional text. For many of these new content types methods have been identified to enable accessibility support, primarily in the EPUB3 format, but some of these potential solutions remain theoretical in nature and are not currently practiced. If you are planning to add any of these features to your eBooks, it is recommended that you conduct additional research and seek further advice on making them accessible.

Complex content

If the content of your publication extends beyond text in a single language, additional work may be required to add metadata and encode the complex content. Support for scientific notation like chemistry and complex mathematical equations is supported in some eBook formats like EPUB3 and has the potential to be fully accessible. These will not be converted automatically from word processing applications and will require work to edit into the converted eBook document. Equally, text which is in multiple languages can also be made accessible with additional effort in the eBook creation process, to ensure the content is rendered properly especially in braille and audio.

Interactivity

The addition of interactivity in eBooks has been likened to a move away from conventional publishing and closer to packaging a webpage into a standalone document which, in many ways, is an accurate description since many of the same technologies are utilised in both arenas. Interactivity in eBooks allows authors to insert tests, puzzles and games into their eBooks. It also allows books to become more interactive, with a book adjusting to reference information provided by the user, for example, changing the name of the princess in a child's story book. These types of eBook are in their infancy and, as a result, often require advanced eBook creation skills to create and they should follow the industry guidance for good practice in eBook creation and web development to ensure accessibility requirements are met.

Multimedia

It is also possible to embed video, audio and animations into an eBook. Once again, this is a fairly complex procedure but it is technically possible to make multimedia fully accessible, typically by providing an alternate version of each type of media (e.g., a video with additional descriptions for people with sight loss, along with captions or a text transcript for people with hearing loss).

8. Additional Considerations

Digital Rights Management

The system designed to protect eBooks from unauthorised copying, Digital Rights Management, restricts the devices or reading systems on which an eBook can be opened. This technical protection measure does not always impact the accessibility of the eBook but, on occasion, can prevent access by specialist software. If the retailer selling the eBook has created a suite of accessible reading systems, one of those options may present a suitable solution. Where a retailer does not provide an accessible reading system and the Digital Rights Management technology prevents an eBook from being read on an accessible reading system developed by a third party, the protection system then becomes a barrier to access. To reduce the impact that Digital Rights Management might have on accessibility, authors should publish with a retailer that offers a wide range of accessibility support in their reading systems.

Fixed layout

Some titles with rich imagery and complex layout can struggle with the more fluid layout of an eBook, which is typically designed to reflow as the text changes size to fill the page. The new EPUB3 format offers more support to complex layouts which require a higher level of design control when displayed on different screen sizes and need to adjust that presentation when text is resized. This technology is at an early stage and the alternative suggestion is to lock down the presentation of the book to ensure a strong visual design. While this may be visually appealing to some, it presents a series of accessibility barriers to people who need to enlarge or customise the presentation of the text. To improve accessibility, eBooks should not be locked to a fixed layout.

9. Checklist of accessibility considerations when self-publishing

To help summarise some of the key messages in this guide, the following checklist of considerations has been developed as you progress the self-publishing process.

EBook technologies offer a life-changing opportunity for people with print disabilities to access publications they may otherwise never be able to read. By considering accessibility in the creation of your publication, you not only enable people with print disabilities to access your work, you open up opportunities for a much wider readership to buy and enjoy your creation.

1. Document formatting:

- Is your source document formatted with Styled Heading Levels?
- Are Heading Levels applied consistently throughout the document?
- Is Character Formatting minimal and not used to convey essential information?
- Do all Images conveying information have captions and/or alt text?
- Are any Tables used small and any key trends described in the text?

2. EBook format choice

- Is your choice of eBook format capable of supporting an accessible version of your publication?

3. Self-publishing retailers

- Does your chosen publishing retailer support the level of accessibility required for your publication?
- Are you happy that the Reading Systems offered by your chosen retailer provide an appropriate level of accessibility?
- Have you reviewed the guidance provided by your retailer?

4. EBook challenge areas

- Has assistance been sought for complex content, multimedia or interactivity?
- Is any multimedia also offered in alternate accessible formats to support people who cannot see or hear it?
- Will Digital Rights Management present an accessibility barrier for your chosen vendor?
- If you are interested in publishing a fixed layout title, are you fully aware of the accessibility limitations and implications of your choice?

5. Find out more

- Did you explore the additional resources in the further information section?
- Have you checked with your chosen retailer about latest developments in the accessibility of their service and reading systems?

10. Glossary of terms

Alt text – An alternative textual description commonly applied to images, designed for people who are unable to access the original visual image, when the alt text can be played in audio.

Author Publisher – The person who created the original Work which they would like to publish and, in this process, also the person who has a relationship with an eBook Retailer to make the book available.

eBook Retailer – The technology company which establishes a formal relationship with the Author Publisher, accepting their Work in a digital form, automatically converting it and making it available through their eBook shop.

Intermediaries – Optional third party organisations which offer to work for the Author to process and submit their Work to an eBook Retailer, managing the technology and assisting with the legal relationship.

Mark-up – Encoding of a document which provides additional information typically used to control the presentation of document elements.

Print Disability – Term encompassing all people with a disability which prevents them from reading conventional publications, encompassing a diverse range of physical, sensory and cognitive disabilities.

Reading System – Because the term “eBook reader” can confusingly refer to both a user and the piece of technology rendering an eBook, the industry has adopted the term Reading System to reference a tool used to access and navigate the eBook. This could be a conventional piece of software for a desktop computer, an App for a smart phone or tablet or a dedicated piece of technology. All the major Retailers have their own dedicated Reading Systems which have to be used to access their eBooks.

User – The customer of the Retailer who buys the eBook and reads it on their Reading System of choice. In the context of this document the user is a person with a print disability, and the Reading System may need to have special qualities for the eBook to be accessible.

Work – The book content or intellectual property created by the author.

11. Further resources

Accessible Publishing

Accessible Books Consortium
http://www.accessiblebooksconsortium.org/

Manuscript Document Formatting

WebAIM guidance creating accessible Word documents:
http://webaim.org/techniques/word/

Microsoft Style basics in Word:
https://support.office.com/en-us/article/Style-basics-in-Word-d382f84d-5c38-4444-98a5-9cbb6ede1ba4#

Libreoffice Writer Guide(PDF):
https://wiki.documentfoundation.org/images/e/e6/WG42-WriterGuideLO.pdf

OpenOffice Writer guide (PDF):
http://www.openoffice.org/documentation/manuals/userguide3/0200WG3-WriterGuide.pdf

Image descriptions

Digital Image and Graphic Resources for Accessible Media (DIAGRAM):
http://diagramcenter.org/

W3C Web Accessibility Tutorial on image:
http://www.w3.org/WAI/tutorials/images/

W3C Alt text decision tree:
http://www.w3.org/WAI/tutorials/images/decision-tree/

Reading System Accessibility

EPUB 3 support on reading systems, including some accessibility tests:
http://www.epubtest.org/

RNIB Video of Kindle Fire HD accessibility features:
https://www.youtube.com/watch?v=fquYkkmbFgQ

EBook format accessibility

IDPF EPUB3 Accessibility Guidelines:
http://www.idpf.org/accessibility/guidelines/

Kindle Format 8:
http://www.amazon.com/gp/feature.html?docId=1000729511

Creating accessible PDF files (PDF):
https://www.adobe.com/enterprise/accessibility/pdfs/acro6_pg_ue.pdf

Accessibility for iOS Developers:
https://developer.apple.com/accessibility/ios/

Accessibility for Android Developers:
http://developer.android.com/guide/topics/ui/accessibility/index.html

Manuscript formatting

Nook MS Word formatting advice:
http://www.nook.com/services/cms/doc/nookpress/gb/en_gb/faq/formatting-guidelines-word.html

Kindle publishing guidelines (PDF):
https://kindlegen.s3.amazonaws.com/AmazonKindlePublishingGuidelines.pdf

Apple iBooks Author: How to make your books accessible:
https://support.apple.com/en-us/HT202371

Apple Creating Accessible iBooks Textbooks with iBooks Author (free iBooks publication):
https://itunes.apple.com/us/book/creating-accessible-ibooks/id569179589?mt=13

Kobo Writing Life User Guide (PDF):
http://download.kobobooks.com/writinglife/Kobo/en-US/KWL-User-Guide.pdf

Kobo Writing Life FAQ (PDF):
http://download.kobobooks.com/writinglife/Kobo/en-US/KWL_FAQ.pdf

Kobo Writing Life Content Conversion Guidelines (PDF):
http://download.kobobooks.com/writinglife/en-US/KWL-Content-Conversion-Guidelines.pdf

12. Image credits

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- Photo of man in wheelchair – under standard licence from Shutterstock reference 25994161
- Chemistry image – from page 34 of “Annual report of the Police Commissioner for the City of Boston”. Book available on Archive.org, image available on Flickr – identified as having no known copyright restrictions.
- Illustrations of Finches – from page 442 of "Journal of researches into the natural history and geology of the countries visited during the voyage round the world of H.M.S. 'Beagle,' under the command of Captain Fitz Roy" (1913). Book available on Archive.org, image available on Flickr – identified as having no known copyright restrictions.

18 How Multimedia Can Improve Learning and Instruction

Richard E. Mayer

The Multimedia Principle

Over the course of human history, the primary mode of communication in education has been with words, including spoken words (e.g., in lectures) and printed words (e.g., in books). This chapter explores the straightforward idea that human communication can be improved when pictures are added to words. In short, the idea motivating this chapter is that people learn better from words and pictures than from words alone. This statement summarizes what has been called the *multimedia principle*, which has become a fundamental principle of instructional design based on a growing body of research evidence (Butcher, 2014; Clark & Mayer, 2016; Mayer, 2009, 2014a).

Multimedia instruction (or a multimedia instructional message) refers to a lesson containing both words and pictures, where the words can be in spoken form or printed form and the pictures can be in static form (such as illustrations, charts, graphs, or photos) or dynamic form (such as animation or video). Multimedia instruction – educational communications that use words and graphics – can be presented in books, in live slideshow presentations, in e-learning on computers, or even in video games or virtual reality.

The rationale for multimedia instruction is both practical and theoretical. On the practical side, the multimedia principle – i.e., adding pictures to words – has potential to contribute to the science of instruction by improving how well students understand academic material; and, on the theoretical side, the multimedia principle has the potential to contribute to the science of learning by yielding the basis for theories of how people learn authentic academic content rather than contrived laboratory materials.

The goal of this chapter is to explore the potential of the multimedia principle for improving how people understand communications about academic content, as measured by their ability to take what they have learned and apply it to new situations (i.e., to be able to solve transfer problems). After a brief introduction, this chapter explores the historical foundations of multimedia learning, the evidence for the multimedia principle, the theoretical basis for how the multimedia principle works, the instructional implications of the multimedia principle, and future directions for the multimedia principle.

Preparation of this chapter was supported by Grant N000141262046 from the Office of Naval Research.

Historical Overview of the Multimedia Principle

The multimedia principle is at once both an old idea, dating back hundreds of years to the work of Comenius on the first multimedia textbook in the seventeenth century, and a new idea, inspired by ever-expanding advances in computer technology that allow dazzling graphics in the digital age.

The first children's multimedia textbook was published in Nuremberg in 1657 by John Amos Comenius. His book, *Orbis Pictus* (translated as "the world in pictures" or simply "visible world"), contained nearly 200 pages, with each page containing a black line drawing ranging from the parts of a house to a barbershop to creatures that live on land and water. Each element in the drawing was numbered, and below was a legend that gave the name in Latin and in the language of the reader for each numbered object, along with some description. The goal was to provide to children "a picture and nomenclature of all the chief things in the world . . . so they may see nothing which they know not how to name and that they may name nothing which they cannot show." Comenius' guiding theory was that "there is nothing in the understanding, which was not before in the sense," which is consistent with the premise of the cognitive theory of multimedia learning that understanding is enhanced when learners can mentally connect words and graphics. On the practical side, *Orbis Pictus* became the bestselling textbook in Europe for a century, insuring its place as the world's first educational classic. In the subsequent centuries, picture books became the staple of children's textbooks, but modern analyses of the use of illustrations in textbooks show that most serve little or no pedagogical value and in some cases can even be distracting (Levin & Mayer, 1993).

Advances in computing technology in today's digital age have reignited educators' interest in multimedia forms of communication because of the ease with which it is now possible to render illustrations, photos, animation, and video and incorporate them with audio and text. Access to the Internet, mobile computing, and interactive virtual reality have made multimedia learning available when and where the learner wants it. Such advances have prompted calls for expanding the concept of literacy to new media in which students learn to create and comprehend multimedia messages (Mayer, 2008). Today's forms of multimedia instruction have expanded beyond paper-based formats to live slideshow formats to computer-based formats, including e-learning, video games, and virtual reality.

However, just because an educational technology exists does not mean that it will be used productively. For example, Cuban (1986) provides a history of educational technology in the twentieth century, including motion pictures in the 1920s, radio in the 1930s, educational TV in the 1950s, and machine-based programmed instruction in the 1960s. In each case, strong claims were made for the educational potential of the cutting-edge technology of the day, but, within a decade, it became clear that the technology had failed to revolutionize education. Today's cutting-edge technologies have prompted some visionaries to call for revolutionizing education – putting multimedia learning experiences online and making better use of game-like activities to accelerate learning (Gee, 2003; McGonical, 2011; Prensky, 2006; Schank, 2002).

The lessons concerning the educational technologies of the twentieth century should caution us to replace a *technology-centered approach* – designing instruction based on what cutting-edge technology can do without regard to how people learn – with a *learner-centered approach* – designing instruction, often multimedia instruction, based on an understanding of how people learn regardless of the medium used to deliver the instruction (Mayer, 2009). This chapter takes a learner-centered approach to designing multimedia instruction in the digital age based on the idea that instructional media do not cause learning but rather instructional methods cause learning (Clark, 2001). The next sections examine what the research has to say about how to design effective multimedia learning experiences for learners.

Evidence Concerning the Multimedia Principle

I stumbled into the field of multimedia learning about thirty years ago as part of my search for techniques that help people learn in ways that allow them to subsequently apply what they have learned to new situations. I was trying to figure out how to help people understand scientific explanations of how cause-and-effect systems work. For example, consider a verbal description of how a bicycle tire works: "When the handle is pulled up, the piston moves up, the inlet valve opens, the outlet valve closes, and air enters the lower part of the cylinder. When the handle is pushed down, the piston moves down, the outlet valve opens, and air moves out through the hose." This is a somewhat accurate – if brief – explanation of how the pump works, but you may wonder how well people understand this communication.

Our research shows that after students listen to this explanation, they are not able to generate many useful answers to transfer questions such as the troubleshooting question, "Suppose you push down and pull up several times but no air comes out. What could have gone wrong?," or the redesign question, "What could be done to make a pump more effective, that is, to move more air more rapidly?" (Mayer & Anderson, 1991).

However, consider what happens if we add a simple animation depicting the movement of the handle, piston, and valves in a pump in sync with the narration, as summarized in Figure 18.1. Our research (Mayer & Anderson, 1991) shows that students who received multimedia instruction generated more than twice as many useful answers to transfer questions than students who received only the narration without any animation. The effect size was greater than $d = 1$, which means that adding the animation to the narration pushed transfer performance up by more than one standard deviation, which is considered a large effect for an instructional intervention.

Overall, in each of the eight experimental comparisons conducted in our lab involving brief explanations of how pumps work, how car braking systems work, how electrical generators work, how lightning storms develop, and how to add and subtract with signed numbers, students who learned with words and graphics performed better than students who learned with words alone, yielding a median effect size of $d = 1.39$ (Mayer, 2009). Being able to improve transfer

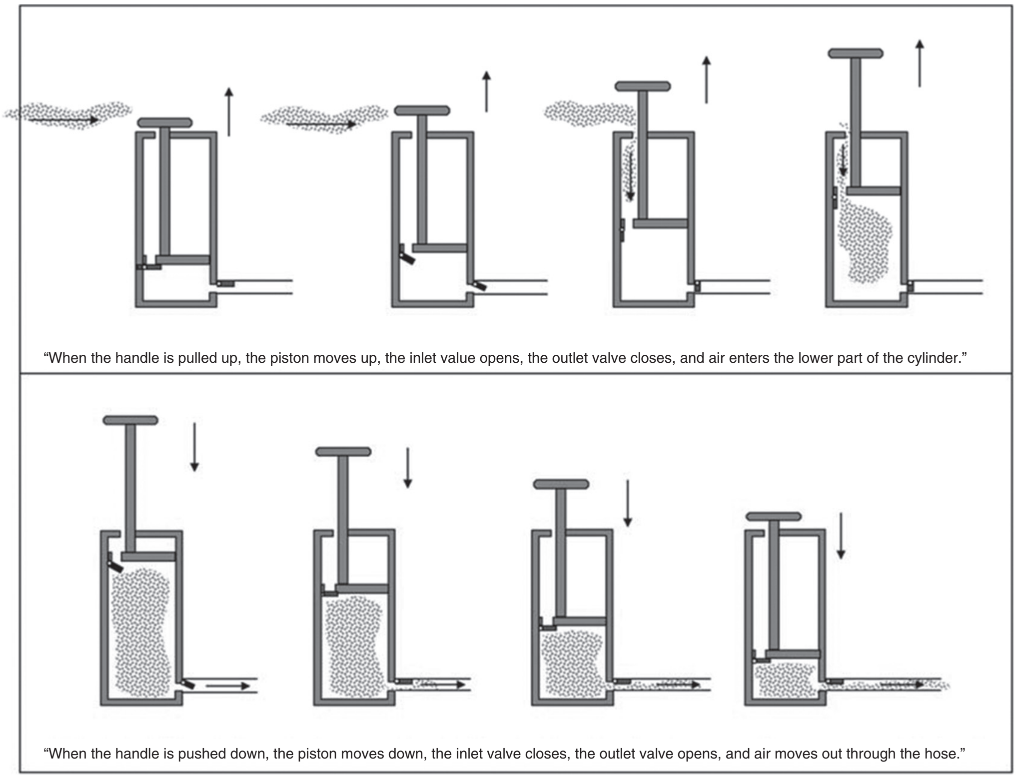


Figure 18.1 *Frames from narrated animation on how a bicycle tire pump works*

performance by more than a standard deviation is an exciting prospect because most instructional interventions do not generate that level of effect (Hattie, 2009). The next step in this research program was to determine how best to design multimedia instruction.

How the Multimedia Principle Works

In order to explain the multimedia principle and to determine how best to design multimedia instruction, classic theories of learning based mainly on rote learning of word lists need to be modified and expanded. For example, an explanation for the multimedia principle is provided by the cognitive theory of multimedia learning, as summarized in Figure 18.2 (Mayer, 2009, 2014a). The cognitive theory of multimedia learning is based on three key ideas from cognitive science:

Dual-channel principle: The human information processing system contains separate channels for verbal and pictorial information (Paivio, 1986; Baddeley, 1992). This is reflected in a verbal channel across the top row of Figure 18.2 and a pictorial channel across the bottom of Figure 18.2.

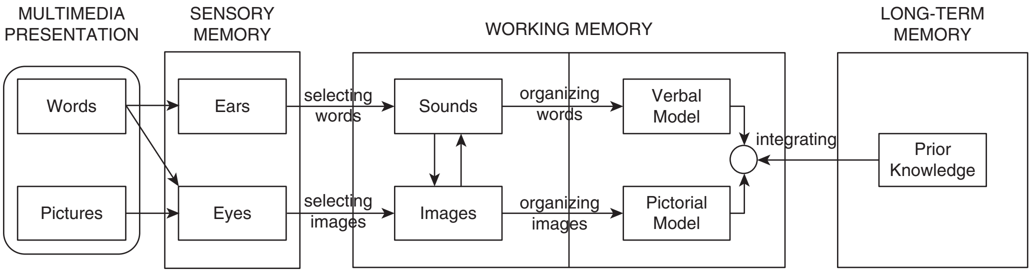


Figure 18.2 *Cognitive theory of multimedia learning*

Limited capacity principle: Only a few items can be processed in a channel at any one time (Baddeley, 1992; Sweller, Ayres, & Kalyuga, 2011). This is reflected in the working memory box in the middle column of Figure 18.2.

Active processing principle: Meaningful learning requires appropriate cognitive processing during learning, including attending to relevant information, mentally organizing it into a coherent structure, and integrating it with relevant prior knowledge (Mayer, 2009; Wittrock, 1989). This is reflected in the arrows for selecting, organizing, and integrating in Figure 18.2.

The boxes in Figure 18.2 represent memory stores and the arrows represent cognitive processes during learning. The first box in Figure 18.2 consists of the multimedia instructional message, which consists of words and pictures. The second box represents *sensory memory* – spoken words are held briefly in auditory sensory memory whereas pictures and printed words are held briefly in visual sensory memory. If the learner pays attention, as indicated by the *selecting* arrows, some of the words and images are transferred to *working memory* for further processing within a system that has limited processing capacity in each channel. In working memory, the learner can arrange words (including printed words transformed from the visual channel) into a verbal model and images into a pictorial model, as indicated by the *organizing* arrows. The final box is *long-term memory*, which contains a permanent storehouse of knowledge. The learner activates relevant prior knowledge and brings it into working memory, where it is connected with the incoming information and where the verbal and pictorial models are connected, as indicated by the *integrating* arrows.

Overall, meaningful learning occurs when the learner engages in appropriate cognitive processing during learning, including selecting relevant words and images from the multimedia message for further processing in working memory, mentally organizing the words into a coherent structure (or verbal model) and the images into a coherent structure (or pictorial model), and integrating the verbal and pictorial representations with each other and with relevant prior knowledge activated from long-term memory. The main challenge in instructional design is to guide learners to engage in these process, while not overloading their limited processing capacity in each channel of working memory. This challenge can be addressed by designing multimedia instruction in ways that minimize extraneous processing (i.e., cognitive processing that does not support the instructional objective, which can be caused by poor instructional design), manage essential processing (i.e., cognitive processing aimed at representing the presented material in working memory, which depends on the complexity of the material for the learner), and foster generative processing (i.e., cognitive processing aimed at making sense of the material, which depends on the learner's motivation to exert effort). In short, designing effective multimedia instruction requires not only presenting the relevant material but also guiding the learner's cognitive processing of the material.

Implications of the Multimedia Principle for Instructional Design

In attempting to apply the multimedia principle to practical educational venues such as classroom instruction, textbooks, and online instruction, it becomes clear that some ways of incorporating graphics are more effective than others. This section explores principles for how to design multimedia instruction that are based on replicated research findings (as reported in primary source publications) and grounded in cognitive theories of how people learn.

Table 18.1 lists eleven evidence-based principles for the design of multimedia instruction – including slideshow presentations, textbooks, online instruction, and educational games. The first column gives the name of the principle, the second column gives a brief description of the principle, the third column lists the median effect size based on published experiments comparing the transfer test performance of students who learned with the standard version of the lesson versus those who learned with an enhanced version that added the target feature, and the fourth column shows the number of experiments showing a positive effect out of the total number of experiments. We focus on principles that yield median effect sizes greater that d = 0.40, which is considered substantial enough to be practically important for education (Hattie, 2009).

The first five principles address the instructional goal of reducing extraneous processing – cognitive processing during learning that does not support the instructional goal. The theoretical rationale for reducing extraneous processing is that working memory capacity is limited, so if a learner allocates too much cognitive processing capacity to extraneous processing during learning there will not be enough cognitive capacity left to fully engage in essential processing (i.e., cognitive processing aimed at mentally representing the essential information in working memory) and generative processing (i.e., cognitive processing aimed at reorganizing the material and integrating it with relevant knowledge activated from long-term memory).

The *coherence principle* is that people learn better when extraneous material is excluded rather than included (Mayer, 2009; Mayer & Fiorella, 2014). Extraneous material includes unneeded detail in graphics, background music, or interesting but irrelevant facts in the text. For example, consider a slideshow lesson on how a virus causes a cold, such as exemplified in Figure 18.3 (Mayer et al., 2008). In the slide, we

Table 18.1 *Evidence-based principles for the design of multimedia instruction*

Principle	Description	ES	No.
Principles for reducing extraneous processing in multimedia learning			
Coherence principle	Eliminate extraneous material.	0.86	23/23
Signaling principle	Highlight essential material.	0.41	24/28
Spatial contiguity principle	Place printed words near corresponding graphics.	1.10	22/22
Temporal contiguity principle	Present corresponding narration and graphics simultaneously.	1.22	9/9
Redundancy principle	Do not add printed onscreen text that duplicates narrated graphics.	0.86	16/16
Principles for managing essential processing in multimedia learning			
Segmenting principle	Break lesson into manageable parts.	0.77	10/10
Pretraining principle	Provide pretraining in names and characteristics of key elements.	0.75	13/16
Modality principle	Present words in spoken form.	0.76	53/61
Principles for fostering generative processing in multimedia learning			
Personalization principle	Use conversational language.	0.79	14/17
Voice principle	Present spoken text with an appealing human voice.	0.74	5/6
Embodiment principle	Use humanlike gestures.	0.40	13/13

Note. ES = median effect size based on Cohen's *d*; No. = number of positive effects out of total number of comparisons.

have added two sentences at the end of the paragraph that present an interesting but irrelevant fact (which can be called a *seductive detail*). Students learned better when seductive details were excluded from the virus lesson ($d = 0.80$). Overall, across twenty-three of twenty-three experimental comparisons, students performed better on transfer tests when extraneous material was excluded, yielding a median effect size of $d = 0.86$, which is considered a large effect. Thus, more learning occurs when less is presented, that is, when the instructional message is kept as simple as possible. Some possible boundary conditions are that the coherence principle applies most strongly for learners with low working memory capacity, when the lesson is presented at a fast pace not under the learner's control, and when the extraneous material is highly distracting (Rey, 2012).

The *signaling principle* (also called the *cueing principle*) is that people learn better when essential material is highlighted (Mayer, 2009; Mayer & Fiorella, 2014; van Gog, 2014). Highlighting of printed text can involve the use of color, underlining, bold, italics, font size, font style, or repetition. Highlighting of spoken text can involve speaking louder or with more emphasis. Highlighting of graphics includes the use of arrows, color, flashing, and spotlights. For example, in a narrated

Step5: Breaking Free from the Host Cell
The new parts are packaged into new virus within the host cell. The new viruses break free from the host cell. In some cases, they break the host cell open, destroying the host cell in the process, which is called lysis. In other cases, they punch out of he cell membrane surrounding them, which is called budding. A study conducted by researchers at Wilkes University in Wilkes-Barre, Pennsylvania, reveals that people who make love once or twice a week are more immune to colds than folks who abstain from sex. Researchers believe that the bedroom activity somehow stimulates an immune-boosting antibody called IgA.

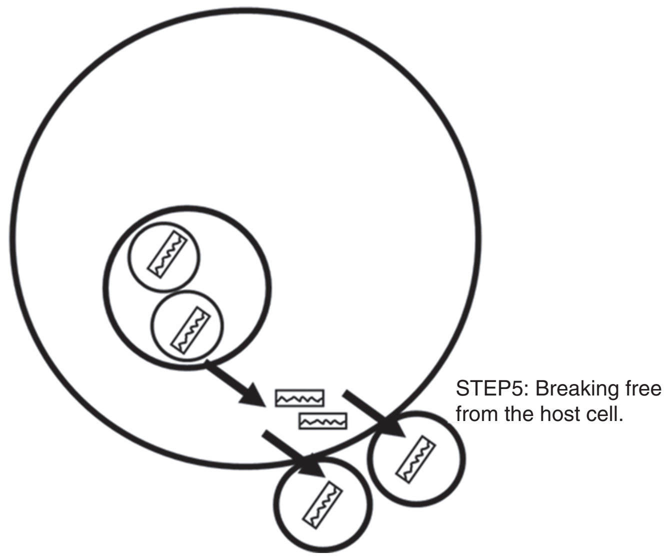


Figure 18.3 *Do people learn better when we add interesting but extraneous text?*

slideshow lesson on how airplanes achieve lift, signaling involved adding headings such as “Wing Shape: Curved Upper Surface Is Longer,” and emphasizing key words, such as the emboldened words in the following phrase: “surface on **top** of the wing is **longer** than on the **bottom**.” Mautone and Mayer (2001) reported better transfer test performance for students who learned from a signaled multimedia lesson than from a nonsignaled lesson (d = 0.65). Overall, there was a positive signaling effect in twenty-four of twenty-eight published experimental comparisons, yielding a median effect size of d = 0.41, which is considered in the small to medium range. Some possible boundary conditions are that the signaling effect can be stronger for low-knowledge learners (Naumann, et al., 2007), when the graphics are complex (Jeung, Chandler, & Sweller, 1997), and when signaling is used sparingly (Stull & Mayer, 2007).

The *spatial contiguity principle* is that people learn better when printed words are placed near to rather than far from corresponding graphics (Ayers & Sweller, 2014; Ginns, 2006; Mayer & Fiorella, 2014). For example, Figure 18.4a shows a version of a lesson on car braking systems with the words presented as a caption at the bottom of the page or screen (i.e., separated presentation) whereas Figure 18.4b shows the words placed near the part of the graphic they describe (i.e., integrated presentation). Johnson and Mayer (2012) reported that students performed substantially better on transfer tests when they received integrated presentations rather than separated

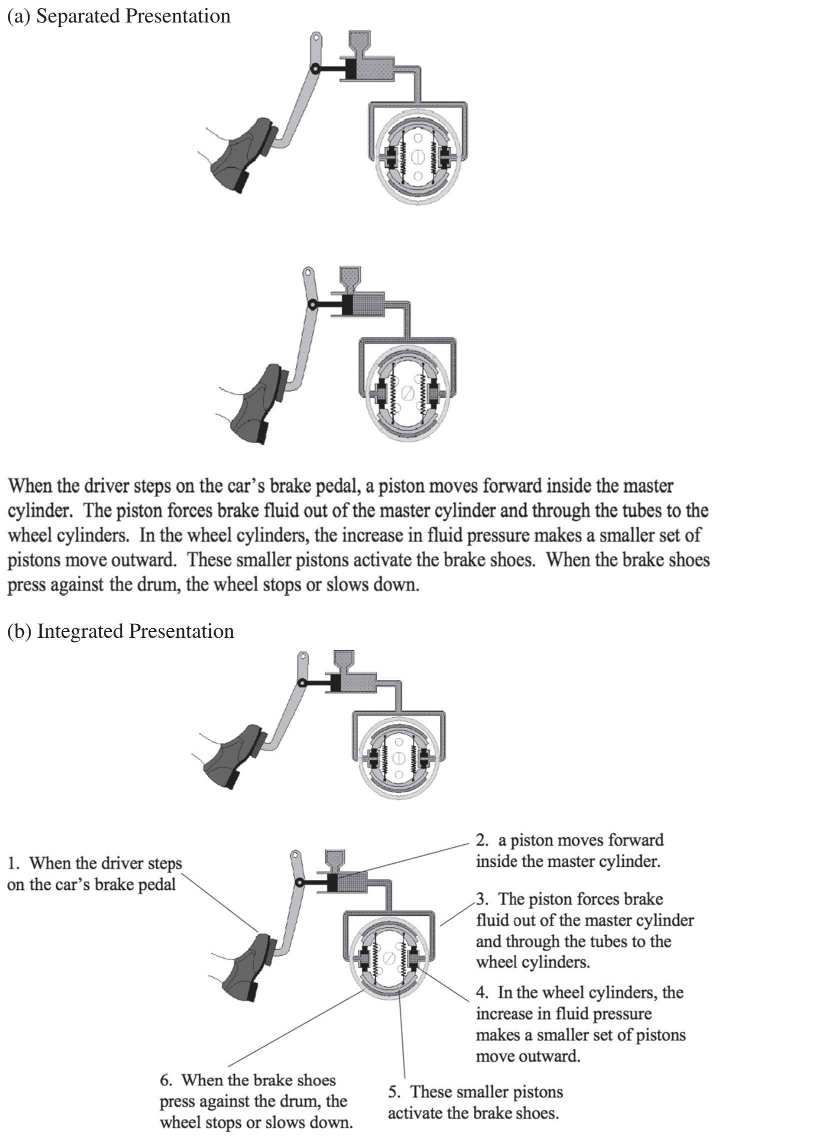


Figure 18.4 *Which instructional method leads to better learning about braking systems?*

presentations, even though the words and graphics were identical in both treatments ($d = 0.73$). Overall, there was a positive effect for spatial contiguity in twenty two out of twenty two published experiments, yielding a median effect size of $d = 1.22$, which is a large effect. Some possible boundary conditions are that the spatial contiguity effect can be stronger when learners are low in prior knowledge (Mayer et al., 1995) and when the material is complex (Ayres & Sweller, 2014).

The *temporal contiguity principle* is that people learn better from a narrated lesson, when the spoken words are presented simultaneously with the corresponding graphics such as drawings, animation, or video (Ginns, 2006; Mayer & Fiorella, 2014). In successive presentation, the spoken words are presented before (or after) the graphics are presented. In nine out of nine published experimental comparisons, students performed better on transfer tests with simultaneous rather than successive presentations, yielding a median effect size of $d = 1.22$, which is a large effect. Some possible boundary conditions are that the temporal contiguity principle is diminished when the material is very simple (Ginns, 2006), when the material is presented in very short chunks (Mayer, et al., 1999; Moreno & Mayer, 1999; Schuler et al., 2012), and when the lesson is slow-paced or under learner control (Michas & Berry, 2000).

The *redundancy principle* is that people learn better from narration and graphics than from narration, graphics, and redundant printed text (Adesope & Nesbit, 2012; Kalyuga & Sweller, 2014; Mayer & Fiorella, 2014). For example, Figure 18.5a shows a slide from a lesson on lightning that includes animation and narration, whereas Figure 18.5b shows a slide that includes animation, narration, and onscreen text that duplicates the narration. Mayer, Heiser, and Lonn (2001) reported that students performed better on transfer tests when they received a narrated animation rather than a narrated animation with redundant onscreen text ($d = 0.77$). Overall, in sixteen of sixteen published experiments, people performed better on transfer tests when redundant onscreen text was excluded rather than included, with a median effect size of $d = 0.86$, which is a large effect. Some important boundary conditions are that the redundancy principle may not apply when no graphics are presented (Moreno & Mayer, 2002), only a few key words are printed on the screen (Mayer & Johnson, 2008), or the onscreen text is worded differently than the spoken text (Yue, Bjork, & Bjork, 2013).

The next three principles in Table 18.1 are aimed at managing essential processing (i.e., cognitive processing for mentally representing the essential material in working

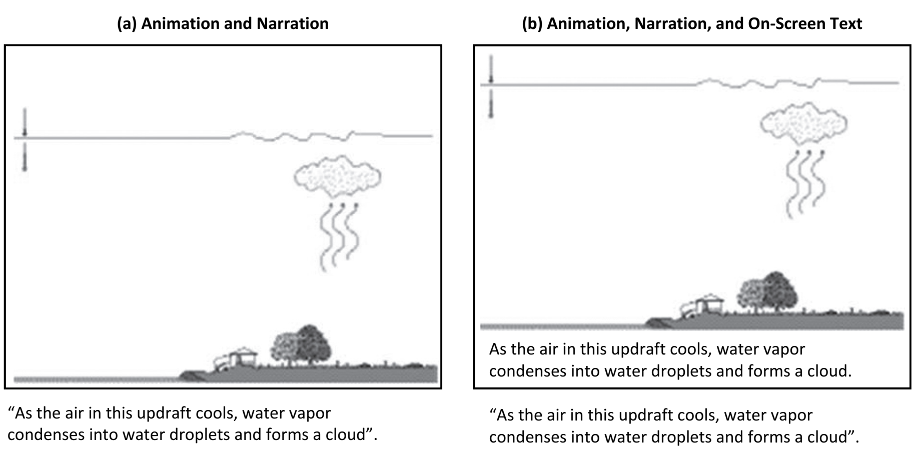
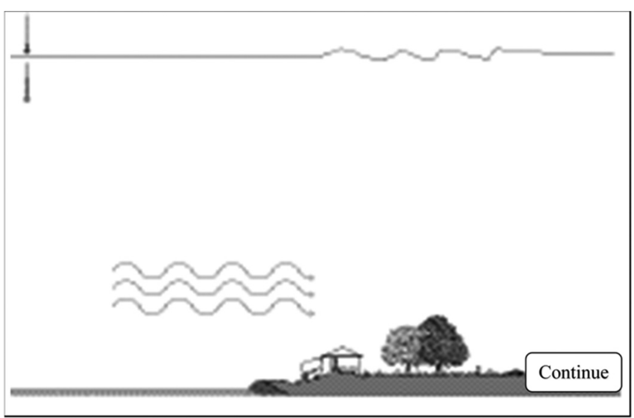


Figure 18.5 *Which instructional method leads to better learning from an online slideshow?*

memory). When the material is complex for the learner, the amount of essential processing required to mentally represent the material may overload working memory capacity. In this case, the learner needs to be able to manage his or her processing capacity in a way that allows for representing the essential material. Three techniques for accomplishing this goal are breaking the essential material into manageable parts (i.e., segmenting), learning about the names and characteristics of key elements before the lesson is presented (i.e., pretraining), and presenting words in spoken form rather than printed form (i.e., modality).

The *segmenting principle* calls for breaking a multimedia lesson into manageable parts (Mayer & Pilegard, 2014). For example, rather than presenting a 2.5 minute narrated animation on lighting formation as a continuous presentation, suppose we break it into sixteen segments, each about 10 seconds long with about one sentence, and allow the learner to click on a CONTINUE key to go to the next segment. A sample slide is shown in Figure 18.6. This design allows the learner to digest one step in the process of lightning formation before going on to the next one. Mayer and Chandler (2001) found that students performed better on transfer tests when they received segmented rather than continuous lessons on lightning formation, with an effect size of d = 1.13. The segmenting principle was supported in ten of ten published experiments, yielding a median effect size of d = 0.79, which is nearly a large effect. Concerning boundary conditions, the segmenting principle may apply more strongly for students with low working memory capacity (Lusk et al., 2009) and for students who are low-achieving (Ayres, 2006).

The *pretraining principle* calls for teaching students about the names and characteristics of key elements before presenting the multimedia lesson (Mayer & Pilegard, 2014). For example, before presenting a narrated animation depicting how a car's braking system works, students can be presented with a diagram of the braking system showing the key parts – e.g., brake petal, piston, wheel cylinders, and brake shoes – as



"Cool moist air moves over a warmer surface and becomes heated."

Figure 18.6 *Do people learn better when a CONTINUE button is added after each segment?*

shown in Figure 18.7. When the learner clicks on a part, such as the piston, the computer shows that the part is called a piston and tells the learner that the piston can move forward and back. Mayer, Mathias, and Wetzell (2002) found that students who received this pretraining before the multimedia lesson performed better on transfer

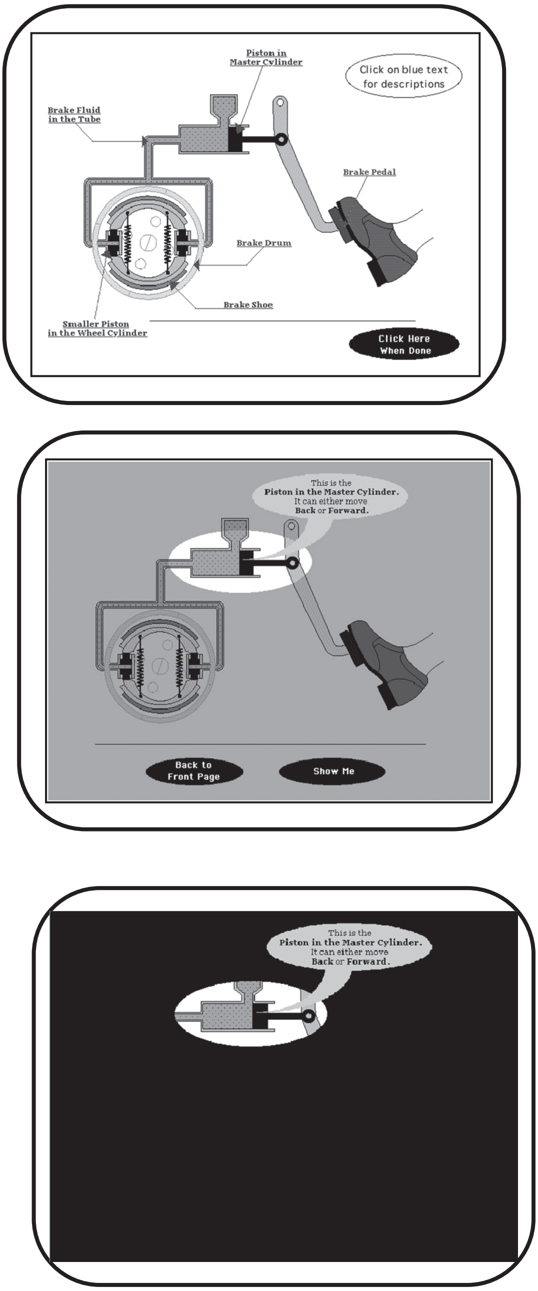


Figure 18.7 *Do people learn better when they receive pretraining in the names and characteristics of the key elements?*

tests than those who received no pretraining (*d* = 0.86). In thirteen of sixteen published experiments, pretrained learners performed better on transfer tests than non–pretrained learners, with a median effect size of *d* = 0.75, which is in the medium range. An important boundary condition is that the pretraining principle may apply to low-knowledge but not high-knowledge learners (Pollock, Chandler, & Sweller, 2002).

The *modality principle* is that people learn better from multimedia presentations when the words are spoken rather than printed (Low & Sweller, 2014; Mayer & Pilegard, 2014). The rationale is that the visual channel may become overloaded by having to process both graphics and printed words, but processing capacity in the visual channel can be freed up when the words are spoken and therefore processed in the verbal channel. For example, Figure 18.8(a) shows a frame from a narrated animation on lightning whereas Figure 18.8(b) shows a frame from the same lesson with words printed on the screen as a caption. Mayer and Moreno (1998) found strong evidence that students performed better on transfer tests when the words were spoken rather than printed for this fast-paced animation that was presented under system control (*d* = 1.49). The modality principle is the most studied of all the multimedia design principles, with positive effects found in fifty-three of sixty-one published experiments, yielding a median effect size of *d* = 0.76, which is in the medium range. Some of the boundary conditions identified in the literature are that the effect can be eliminated when the lesson is self-paced (Tabbers, Martens, & van Merrienboer, 2004) or when the verbal segments are long and complex for learners (Schuler et al., 2012).

The final three principles in Table 18.1 are intended to foster generative processing, that is, cognitive processing aimed at making sense of the presented material. Even if cognitive capacity is available, learners may not be motivated to use it to process the material deeply. Social cues can help motivate learners to engage in deeper processing because people tend to want to understand what a communication partner is telling them. Thus, principles based on social cues are intended to make learners feel as if they are in a conversation with the instructor, that is, they feel that

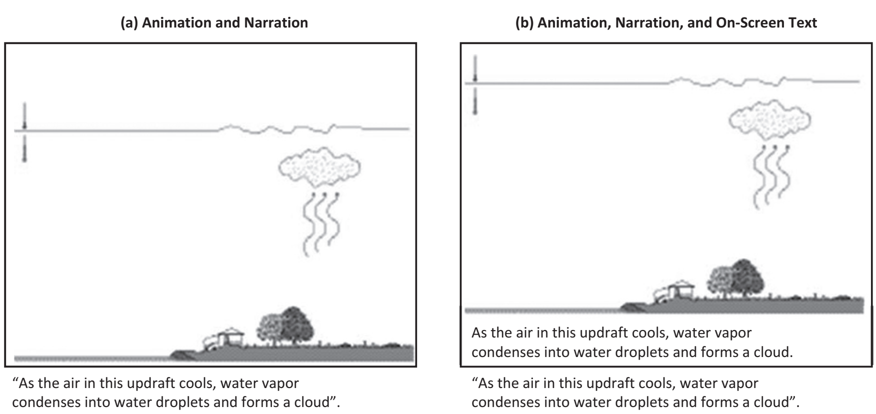


Figure 18.8 *Which instructional method leads to better learning from an online slideshow?*

Table 18.2 *Portions of nonpersonalized and personalized text from a narrated animation on how the human respiratory system works*

Nonpersonalized Version

"During inhaling, the diaphragm moves down creating more space for the lungs, air enters through the nose or mouth, moves down through the throat and bronchial tubes to tiny air sacs in the lungs . . . "

Personalized Version

"During inhaling, your diaphragm moves down creating more space for your lungs, air enters through your nose or mouth, moves down through your throat and bronchial tubes to tiny air sacs in your lungs . . . "

the instructor is a social partner. This approach yields the newest of the multimedia design principles, including using conversational language (personalization principle), using an appealing human voice (voice principle), and using humanlike gestures (embodiment principle).

The *personalization principle* is that people learn better from a multimedia lesson when the words are in conversation style rather than formal style (Ginns, Martin, & Marsh, 2013; Mayer, 2014b). For example, Table 18.2 shows a portion of the words from a lesson on how the human respiratory system works presented in third-person form (e.g., "the lungs") or in first- and second-person form (e.g., "your lungs"). Students performed better on a transfer test when the words were in conversational style (i.e., in first- and second-person form), with an effect size of $d = 0.79$ (Mayer et al., 2004). Overall, there were positive effects in fourteen of seventeen published experiments on personalization (including polite vs. direct wording), yielding a median effect size of $d = 0.79$ which is nearly a large effect. Concerning boundary conditions, the personalization principle works best for less knowledgeable learners (McLaren, DeLeeuw, & Mayer, 2011a, 2011b; Wang et al., 2008) and lower achieving learners (Yeung et al., 2009) as well as with shorter lessons (Ginns et al., 2013).

The *voice principle* is that people learn better from multimedia lessons involving spoken words when the narrator has an appealing human voice rather than a machine voice or an unappealing voice (Mayer, 2014b). In five out of six experimental comparisons, people learned better from narrated animations – such as a 2.5 minute animated presentation on lightning formation (Mayer, Sobko, & Mautone, 2003) – when the words were spoken in an appealing human voice rather than in a machine voice or in an unappealing human voice, yielding a median effect size of $d = 0.74$. An important boundary condition is that the positive impact of a human voice can be overturned by the use of negative social cues such as presenting an onscreen agent that does not engage in humanlike gesturing (Mayer & DaPra, 2012).

The *embodiment principle* is that people learn better from multimedia lessons in which an onscreen agent or instructor uses humanlike gesture (Mayer, 2014b). For example, Mayer and DaPra (2012) presented students with a narrated slideshow lesson on how solar cells work in which an onscreen animated pedagogical agent stood next to the slide (as shown in Figure 18.9) and either displayed humanlike gestures or did not move during the lesson. Students learned better when the

Figure 18.9 *Do people learn better when an onscreen agent uses humanlike gestures or stands still?*

onscreen agent used humanlike gestures ($d = 0.92$). Overall, in thirteen of thirteen published experiments, students performed better on transfer tests when they learned from onscreen agents or instructors that exhibited humanlike gestures, yielding a median effect size of $d = 0.40$. Concerning boundary conditions, the embodiment effect is reduced or eliminated when the lesson contains negative social cues such as a machine voice (Mayer & DaPra, 2012).

What happens when we combine these principles within the context of an actual classroom? Issa and colleagues (2013) compared how beginning medical students learned from a standard slideshow lesson or from a lesson in which the slides were modified based on multimedia design principles such as in Table 18.1. On a transfer test administered four weeks later, students in the modified group outperformed those in the standard group with an effect size of $d = 1.17$, even though the content was the same. This study – and similar ones (Harskamp, Mayer, & Suhre, 2007; Issa et al., 2011) – suggest that applying multimedia principles to the design of classroom instruction can greatly increase student learning.

What happens when we apply multimedia design principles to the design of educational games? In a more recent review, Mayer (2014c) found that students learned more from educational games when they were based on the personalization, pretraining, modality, and redundancy principles. Thus, principles of multimedia design appear to apply in game-based venues as well as in paper-based and computer-based lessons.

In summary, Table 18.1 lists eleven evidence-based principles of multimedia design that are intended to maximize the effectiveness of multimedia instruction. Each has important boundary conditions, largely consistent with the cognitive theory of multimedia learning.

Future Directions for the Multimedia Principle

Some potential future directions for principles of multimedia learning are listed below.

1. Studies examining design principles for multimedia instruction have been forged mainly in short-term laboratory studies, so future research is needed to examine how the principles apply in more authentic educational environments such as with real students in real classrooms and over longer time periods including the use of delayed tests.
2. Studies examining design principles for multimedia instruction have been conducted mainly looking at one feature at a time, so future research is needed to determine what happens when multiple features are used in conjunction with each other.
3. Studies on design principles for multimedia instruction have focused mainly on helping students learn conceptual knowledge (such as explanations of how a scientific system works), so future research is needed to determine whether the principles also apply for other kinds of learning objectives in the revised Bloom's taxonomy including learning facts, procedures, and strategies (Anderson, et al., 2001).
4. As the field progresses, it is useful to develop converging evidence on the boundary conditions for each multimedia design principle. In particular, most of the research supporting this chapter was conducted with low-knowledge learners (or beginners), and there is emerging evidence that the principles may not apply to high-knowledge learners (or experts). Kalyuga (2014) uses the term *expertise reversal effect* to refer to the finding that instructional manipulations that benefit learning for beginners do not work for experts or may even be detrimental to experts. Research is needed to determine if the expertise reversal principle applies to each multimedia design principle.
5. In light of technological advances, it is useful to determine the extent to which multimedia design principles apply to new media such as learning in virtual reality, video games, massive open online courses (MOOCs), and interactive e-books.
6. Finally, as the field progresses, the theories underlying the principles need to be sharpened and expanded to include motivational, metacognitive, affective, and social factors.

What should not change in the future is a focus on rigorous scientific methods grounded in research-based theories of how people learn. Over the past thirty years, educational and cognitive psychology have amassed encouraging evidence that human understanding can be improved substantially when we add appropriate graphics to text. The power of multimedia learning has useful practical implications for the design of instruction and useful theoretical implications for the science of learning. In multimedia learning, pictures do not replace words but rather work together with words to form an instructional message that results in deeper understanding.

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