UNIVERSITY OF CALIFORNIA

Los Angeles

From Codex to Bits: Discourses, Practices and Materialities in the Open Textbook Phenomenon

A dissertation submitted in partial satisfaction of the

requirements for the degree Doctor of Philosophy

in Information Studies

by

Athanasia Chtena

ABSTRACT OF THE DISSERTATION

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University of California, Los Angeles, 2019

Professor Jean-François Blanchette, Chair

Using interviews, observations and a system analysis approach this research project tracks the development and implementation of open textbooks in Californian higher education over 24 months. Open textbooks – which are digital textbooks that can be freely accessed, shared and adapted – are being embraced by governments, philanthropists and educational institutions as a possible solution to the college access and affordability 'crisis' in the United States. Yet, while much work has been done to create, disseminate and champion open textbooks, our understanding of how these resources are impacting upon the higher education landscape remains limited. This study makes the case that it is increasingly crucial to investigate empirically how educational technologies like open textbooks 'come to be' (that is how they are constructed, both socially and materially-technologically), while at the same time assessing how these resources are actually deployed in practice. The study demonstrates that binary conceptualizations of openness (i.e., 'open' vs 'closed') based on formal characteristics (e.g., licensing) are not reflective of how people 'do' openness in practice, and that different needs, values, priorities and interpretations of 'open' give rise to different artifacts in different disciplines and institutional settings. Moreover, the study shows how the frictions of open textbook production, circulation, and maintenance – the labor and expense, cultural barriers, as well as infrastructural limitations – belie the fantasy of open textbooks as a dynamic interface prime for adaptation, modification and remix. Finally, this study challenges persistent narratives about the so-called 'immateriality' of open textbooks by highlighting the durability of print and paper practices within an increasingly digital environment. Ultimately, by placing open textbooks in a wider context, this study questions discourses that assume that educational change is driven by progressive technological advance, and which posit a distinct divide between "open" and "traditional" textbooks, as well as between "new" and "old" technologies more broadly. It argues that educational disruption occurs within existing norms and practices and alongside existing technologies (e.g., print) in a heterogeneous socio-technical field where technological artifacts (e.g., open textbooks) continuously evolve around new innovations (e.g., Big Data).

The dissertation of Athanasia Chtena is approved.

Johanna R. Drucker

Christopher M. Kelty

Cecilia Rios-Aguilar

Jean-François Blanchette, Committee Chair

University of California, Los Angeles

2019

I dedicate this dissertation to my grandmother, who passed away while I was working on this project. This work is also dedicated to all the people who are working on open textbooks – the publishers, designers, librarians, instructors, instructional designers, students, open education researchers—who let me hang around them, generously explained their work to me, and indulged my curiosity with sincerity and good humor, even when some of them weren't exactly sure what I was doing. Thank you all for making this research project possible with your generosity, bluntness and openness – this dissertation would not have come to fruition without you. I would also like to extend special thanks to James-Glapa Grosklag, Peri Klemm, Serban Raianu, Richard Baraniuk, Kathi Fletcher, Ross Reedstrom and the rest of the team at OpenStax, who welcomed me with open arms.

I am grateful – more than he will ever know – to my advisor and mentor, Jean-François Blanchette, who guided me with patience and kindness and kept me on track. He has read multiple drafts of this dissertation (not to mention fellowship proposals, research and teaching statements), and he has always given me feedback at exactly the right level of abstraction that I needed: from high-level thoughts on first-drafts to line-by-line edits on final versions. In addition, he coached me on my job interviews, consoled and counseled me through research crises, provided much-needed space when I was struggling with my health, and wrote numerous recommendation letters for me.

I've been blessed, not just with a wonderful advisor, but a wonderful committee, as well. Johanna Drucker, Christopher Kelty and Cecilia Rios-Aguilar have all supported and challenged me in the right ways, and I am incredibly grateful for their advice and mentorship over the past few years. Johanna's no-nonsense, big-picture feedback always came when I needed it most and Chris played a central role in getting me full access to OpenStax, enabling a huge part of this dissertation research. He also persistently reminded me to not use the term 'ethnography' or 'anthropologist' loosely, and for that I am most grateful.

I am extremely grateful to the Department of Germanic Languages, and in particular Magdalena Tarnawska, for offering me a job year after year and for giving me the opportunity to hone my teaching skills in a variety of courses and areas while working on this project. Of course, I couldn't have written this dissertation without the support of the Department of Information Studies, which has been extremely generous in its support as well. Special thanks to Amy Gershon, for being the best Director of Student Services one could hope for, and an incredibly solid human being as well.

I am also thankful to my family, especially my mother, who supported me gracefully and selflessly during this crazy journey. And, of course, to my non-biological family, my friends and colleagues who made the tough times more bearable and the fun times even better. You know who you are and I'm grateful to know you.

Last but not least, I am thankful to my old mentor and friend, Thodoris Colovos. My dear, thank you for believing in me, for pushing me to my limits, and for showing me how to reach for the stars.

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This work was partially supported by a Dissertation Year Fellowship by the UCLA Graduate Division, and a fellowship by the UCLA Department of Information Studies. I would also like to recognize the GO-GN Global OER Graduate Network and the OER Research Group for their mentorship and support.

Athanasia (Natascha) Chtena is a Doctoral Candidate in the Department of Information Studies at UCLA, where she teaches various classes on technology, politics and society. She is an OER Research Fellow with the Open Education Group and a regular contributor to conversations and collaborative projects in the area of open education, within the US and globally. Her dissertation project is a multi-sited ethnography of open textbook development, distribution and use/reuse in California. More broadly, her research interests include the history of technology, “dead media,” digital futures, theories of materiality, and online and blended learning. Natascha holds a masters in Cultural Studies and Comparative Education from UCLA and a masters in Media Anthropology from the School of Oriental and African Studies, University of London.

CHAPTER 1: INTRODUCTION AND THEORETICAL FRAMING

1.1 Introduction

In the last several years, openness has repeatedly been touted as a possible panacea to the US higher-education ‘crisis,’ brought about in large by harsh budget cuts, rising tuition costs, and mounting student debt. When MOOCs emerged in 2012*,* they were promoted as a way of solving educational inequality by delivering a high caliber education to anyone with an internet connection for free (Lewin, 2012; McKenna, 2012) – a goal that goal didn’t quite materialize. More recently, open textbooks have gained traction in US higher education and have been advocated as a promising means to addressing the rising cost of college course materials in the country (Mulhere, 2015; Senack, 2014; Vitez, 2018). According to data from the US Bureau of Labor Statistics, the cost of textbooks increased by nearly 88% between 2006 and 2016 (BLS, 2016), leading many students either to forfeit buying textbooks (affecting learning outcomes and success rates) or take fewer classes (resulting in a longer time to degree completion) (Florida Virtual Campus 2014; Grasgreen 2014; Senack 2014).

Open textbooks – which are digital textbooks that can be freely accessed, shared and adapted – are being embraced by governments, philanthropists and educational institutions as a possible solution to this problem. Besides the obvious cost savings, one of the main suggested benefits of open textbooks is flexibility to customize them for specific course designs. Content can be adjusted for various student audiences, updated to include current events, or otherwise customized to reflect specific teaching approaches to the subject matter. It is thus believed that open textbooks can potentially promote active learning and, even, spur pedagogical innovation (e.g., Frydenberg & Matkin, 2007; Mason & Kimmons, 2018; Petrides et al., 2011). Yet, while open textbooks are high on the agenda for social inclusion policies and supported by many stakeholders, their use in US higher education has not yet reached a critical threshold (Lieberman, 2018; 2019; Lestch, 2018; Reed, 2018). As well, empirical research on the open textbook phenomenon remains limited.

While a number of recent studies attended to faculty and student attitudes toward open textbooks (e.g., Bliss et al., 2013; Ozdemir & Hendricks, 2015; Pitt, 2015), on student engagement with these resources (e.g., Jhangiani & Jhangani, 2017; Hilton et al., 2013; Fischer et al, 2015) and on cost savings (e.g., Wiley et al., 2012; Hilton et al., 2014) the methods employed by these researchers have been confined largely to self-reported surveys and on case studies in a single institutional or organizational context. So far, no attempts have been made to map the structure of the open textbook ecosystem in the US, conflicts surrounding standardization of content, and the role of interoperability in structuring both systems and markets. In addition, our understanding of how openness is interpreted and implemented by different stakeholders *in practice*, and how that compares to the rhetoric around 'open,' remains narrow. Thus, in this dissertation, I take a systems approach to investigate the reasons behind the slow adoption and uncertainty surrounding open textbooks. Looking at the entire system of open textbook production and circulation, rather than isolated components, helps us identify areas of hindrance in the scalability and sustainability of these resources. My research methods consist of in-depth interviews with key stakeholders, ethnographic observations, and a system analysis of a major open textbook provider. My research sites include several colleges in the Greater Los Angeles Area, as well as a number of open education summits, training workshops for faculty and working group meetings across the state.

1.2 Background and aims of this study

The term 'open' textbook entails at least two distinct meanings: open to access and open to change. The first means that a textbook is free to be accessed without any restriction, whether operational, financial or physical. The second, means that users are free to use or reuse the textbook for purposes including remixing, revising and redistributing. Therefore, an important notion that underpins open textbook production is that of modularity, the degree to which a system's components may be separated and recombined (Russell, 2012; Blanchette, 2011). In contrast with traditional textbooks, open textbooks favor a modular organization so as to support remix and re-appropriation, that is, the possibility of disassembling a textbook into its components, modifying one or more of these components, and reassembling the modified components into a different textbook. By allowing instructors to 'mix and match' components, open textbooks will presumably allow them to develop educational materials that better fit the needs of their students and their specific context.

This malleability makes new demands on institutional and technical infrastructure, such as interoperability, i.e. the capacity of individual textbook components to interface with each other, not just at the level of content, but also at the technical (e.g., encoding) and social (e.g., copyright) levels. Moreover, interoperability is required for content to be repurposed by other platforms and services within the open textbook ecosystem (i.e., online test banks, AI-driven adaptive learning system). Without proper interoperability, open textbooks remain fixed digital objects unable to fulfil their potential for remixing, reuse and customization of content to individual learners. Widespread adoption of open textbooks is thus contingent, among other things, on the definition and adoption of technical standards supporting interoperability.

These technical transformations and possibilities are also inducing various economic shifts intent on disrupting the traditional textbook publishing model. At the institutional level, open textbooks support a radically different division of labor characterized by decentralized intellectual collaboration, participation in the gift economy and the use and reuse of material for the collective benefit of the community. Currently, the majority of open textbooks are created by faculty with minimal institutional and financial support, while traditional publishers and other for-profit companies offer subscription models and value-added services (e.g., adaptive homework systems) that piggypack on existing open textbook content. Macmillan Learning, Pearson, and McGraw-Hill, for instance, have introduced products that intermix open content along proprietary one, raising questions about the shifting nature and meaning of 'open' and how it will evolve in the years to come. Meanwhile, co-operatives and other grassroots organizations have begun to form, to support the creation and sharing of open textbooks, and to explore the potential of an academia-center publishing model, with attendant interoperability challenges.

The stark discrepancy between the promise of open textbooks and their implementation on the ground point to the need to adopt a systemic approach that analyses the flow of content through the various components of the open textbook ecosystem and its structuration by various technical, economic, and institutional requirements – that is how technical, economic and institutional infrastructure are shaping the form of open textbooks, their meaning and the practices surrounding them. Moreover, looking at the entire system of open textbooks production circulation, and use, rather than isolated components, will help us identify areas of hindrance in the scalability and sustainability of open textbooks. Specifically, my study objectives are as follows:

1. To examine how openness is interpreted by relevant stakeholder groups, what it means in practice, and how we can better research and understand it;
2. To analyze how the form and format of open textbooks is being shaped (and reshaped) by the social (e.g., copyright, labor, economics) and technical infrastructure (e.g., software, standards, metadata) in which they are embedded;
3. To investigate the extent to which faculty are revising, remixing and redistributing open textbooks and identify common barriers to these practices;
4. To investigate the role of paper and print in the implementation of open textbooks and students' attitude toward the use of these media.

1.3. Research questions

This dissertation captures the discourses, materialities and practices of open textbooks as they are unfolding in the state of California and asks what their emergence entails for teaching, learning and the higher education sector more broadly. My research methods consist of in-depth interviews with key stakeholders, ethnographic observations, and a system analysis of two open textbook platforms. My research sites include several community colleges and CSU campuses in the Greater Los Angeles Area, as well as a number of open education summits, training workshops for faculty and working group meetings across the state. I use theoretical works about the social construction of technology, the materiality of digital artifacts, critical approaches to infrastructure building, as well as archaeological approaches to the study of media artifacts to contextualize data collected through interviews, online research and participant observation.

The research is organized around three questions, which are as follows:

1) Interpretations of 'open:' How is openness interpreted and understood across different types of institutions, markets and stakeholder groups, and how do their goals for open textbooks differ? How are these different visions and priorities shaping how open textbooks are implemented in undergraduate education in California?

2) Modularity and remix: How are OpenStax textbooks designed, developed and delivered? How modular, interoperable and customizable are their components? And to what extend are users taking advantage of open licenses to adapt, remix and redistribute them?

3) Materiality in the classroom: How are open textbooks implemented and used in the classroom? What role, in particular, does paper play in classroom practice? And how does actual practice compare to the rhetoric of immateriality and paperlessness that surrounds open textbooks?

In the next section, I summarize recent literature emerging from STS and neighboring disciplines on the social shaping of technology and the technological shaping of society. I draw on constructivist and new materialist approaches to the study of educational technologies, as well as sociological approaches to the study of digital systems and infrastructures, to establish a theoretical foundation for the subsequent exploration and analysis of open textbooks. I follow that by detailing the three scholarly contribution of this dissertation to Information Studies and Educational Technology Research. I conclude with a plan for the rest of the dissertation.

1.4. Theoretical background and contributions

> [It] is often believed that theory is a sort of idle luxury or even a fraud, purporting to lay down encompassing generalizations which in fact have not been 'empirically established.' On the contrary, it is in just such fields as ours that theory is of the greatest importance, though much neglected. For we do in fact

> already know a great deal about education and development; the problem is rather to marshal that knowledge in a coherent usable form. Empirical investigations conceived within such a framework of theory can react upon, can modify or extend knowledge. They cannot amount to much without it. (Hawkins, 2007/1972, p. 288)

This section functions as a literature review for the theoretical concepts that have shaped my research. It draws upon a number of different theoretical areas and attempts to weave together various concepts. I acknowledge the potential drawbacks of this approach, in that each concept may not be given a full and in-depth treatment. However, I suggest that the advantages of this approach are in the creative possibilities of making links and relations between ideas that can be put to work in the study of open textbooks.

The turn towards computer-based teaching and learning over the past twenty years has been steadily accompanied by the promise to revolutionize and revitalize the university sector. For instance, Massive Open Online Courses (MOOCs) were believed to be the panacea for the financial sustainability of higher education – i.e., MOOCs would provide a cheap alternative to educate the masses and alleviate poverty – and also proposed an alternative structure thought to destabilize the 'outmoded,' 'outdated' and 'inefficient' university lecture. Similarly, speculation about the possible impact of open textbooks on education has ranged from expectations of reduced costs and greater access to predictions of change in scholarly production and publishing, as well as in university teaching and learning. Assumed here, is that the mere adoption of a technology will 'naturally' evoke change at the personal, institutional and cultural levels. Yet, previous studies have shown that individual and institutional change in education occurs at levels which are beyond the provision of technology alone, and that claims about the applications (and desired 'effects') of educational technologies can differ widely from the reality of their use (e.g., Aibar, 2014; Crooks, 2016; Selwyn, 2007). At the same time, a lot of the studies that look at the social dimensions or social shaping of ed-tech tend to 'black box' the technological and material aspects of technology (Johri, 2011; Roehl, 2012; Voithofer, 2012)

Below, I map out a theoretical basis that will allow me to consider open textbooks and the practices surrounding them as a merger of both social and technical elements in which no primacy is given to either of the two – that is, neither to the social nor to the technical. A 'way in' into these matters are what we call 'socio-technical approaches,' an umbrella term for currents in fields such as science and technology studies, infrastructure studies, material culture studies and political ecology (e.g., Latour, 1993; 2005; Law & Biker, 1992; Orlikowski, 1996; Pickering, 2010; Silver & Marcus, 2013). I argue that socio-technical (or socio-material) thinking can play a critical role by helping us overcome the inherent dualism in the educational technology literature between the social implications of technology use and the material aspects of technology design – a dualism that either privileges the social or the technical while failing to provide proper attention to socio-technical forces and dynamics and how they are entangled in complex action and movement.

1.4.1. The social construction of technology

Technological determinism[1] has been largely sidelined in the scholarly study of technology, however, it is still frequently found in the media and in business. In education, it betrays itself in reference to technological innovations that will create new learning experiences, 'fix' social inequalities, or 'disrupt' existing teaching practices. The technological deterministic argument

[1] A detailed overview of technological determinism is beyond the scope of this chapter. See Misa (1988) or Smith & Marx (1994) for a broad, yet detailed overview of the concept. For a discussion of technological determinism in education research, see Oliver (2011) and/or Bromley (1997).

sees technology as separate from society – a force which develops autonomously, according to its inner logic (Williams and Edge, 1996). In such accounts, forces such as economics, politics, institutionalization and ideology are obscured or ignored. "To ask, therefore," Jones & Bissell (2011) have argued, "what the effect of a particular technology on education might be is implicitly to adopt a determinist stance" (p. 286).

Social constructivists, on the other hand, reject the idea that technology develops independently from society. According to the social constructivist view, technology has no inherent meaning. Instead, there are social forces at play that shape its development, adoption, use, and meanings. Rather than deny that technology shapes society, however, social constructivism suggests that forces may move in both directions, i.e. that technology shapes society *and* society shapes technology. One particular strand of social shaping, is the Social Construction of Technology (also referred to as SCOT), a theory and methodology developed by Pinch & Bijker (1984), which is concerned with how technological designs are adopted and become embedded in social practices and social institutions. According to Pinch & Bijker (1984), the design of technology is an open process that can produce various outcomes and is dependent on the social circumstance of development. One of the main premises of SCOT is that there are no 'right' and 'wrong' technologies, that any technology "could have been different" (Prell, 2009) and that, overall, technological artifacts don't result from careful, rational planning, but are instead shaped by the actors involved – directly and indirectly – in their design. Thus, the ways a given technology is used cannot be understood without understanding how that technology is embedded in its social context.

A concept emphasized by SCOT is *interpretative flexibility*, in which various social groups (called *relevant social groups*) associate different meanings with technological artifacts;

that is, artifacts are conceived and understood to be different things to different social groups of users. Each group has its own idea of the problem that the new artifact is supposed to solve and, in consequence, its own view of how that artifact should like. A given group may therefore favor a technological design, including components and standards, that may not be favored by competing groups. As such, differences of meaning (and different designs) compete for social acceptance, until such conflicts are resolved and the artifact no longer poses a problem to any relevant social group (*stabilization* and *closure*). Closure is reached when one group's design prevails and the others are forgotten (Pinch and Bijker, 1984) or two or more groups negotiate a compromise (Bijker, 1996) so that no further (or only minor) design modifications occur, and the artifact stabilizes in its final form. In some cases, diagnosed problems are not solved but are instead redefined so that they are no longer problems to the relevant social groups (this is described as *closure by redefinition* (Pinch and Bijker, 1984).

1.4.1.1. How social construction works: from bicycles to open textbooks

In their seminal essay "The Social Construction of Facts and Artifacts: or How the Sociology of Science and Technology Might Benefit Each Other", Pinch & Bijker (1984) use these concepts to describe the development of the safety bicycle, showing how its design was propelled and constrained by societal issues. Pinch & Bijker (ibid.) argue that the development path of the bicycle was far from linear, with various designs being tested and rejected by various groups at various stages. Relevant social groups—including bicycle producers, long-distance cyclists, sports enthusiasts, elderly riders, (dress-wearing) women and 'anticyclists,' to name but a few – responded differently to different designs, finding different advantages and disadvantages as well as meaning in them.

For instance, the bicycle of the Victorian era, called ‘penny-farthing,’ had one very large wheel and one tiny wheel, and was used mostly for sport. While most people agreed that there were problems with it, there was no consensus on how to fix these problems, or even what exactly the problems were. Some found the penny farthing too dangerous (due to concern about falling from height), others hated the idea of seeing women ride such a high-wheeled bike (due to reasons of fashion and etiquette, mainly), while others yet considered it a ‘macho machine,’ as it was mostly used by wealthy young men who wanted to appear superior to walkers and horse riding folks.

Later, many resisted the introduction of pneumatic tires, which, despite making bike riding considerably more comfortable, also required considerable maintenance and were prone to slipping in mud. Over the years development moved in many directions as different social groups identified different problems and solutions. These included safety, ease of manufacture and repair, speed, and ability to manage the roughness of roads. A significant variety of designs emerged (many quite different from what we see today) targeting different audiences, all with varying cultural meanings and different types of affordance and constraints.

Eventually, the modern bicycle prevailed rendering most other designs obsolete. Designers continued - and continue - to make small changes, never however radically altering the design. In this way, Pinch & Bijker (ibid.) show that the design of the bicycle was socially constructed in the sense that the design that prevailed and became mainstream was not the *best* in some objective sense; instead, it was the one that the relevant social groups accepted because they thought it best fit their needs. In fact, problems like slipping in the mud and requiring extra maintenance were never solved *per se*, rather, people ultimately decided that these problems weren't really problems. Pneumatic tires still require inflating and patching, but we've come to see this as simply part of riding a bike, rather than a flaw in the overall design of the bicycle.

If we look at the development of open textbooks over the past decade, we see a similar, nonlinear unfolding and an ongoing competition between different visions of openness pushed forward by different stakeholder groups (e.g., non-profit publishers, for-profits and institutions of higher-ed). For instance, while institutional open textbook providers (e.g., OpenStax, OpenSUNY) generally ensure that all their materials are openly licensed and available for reuse and remix, many individual authors lack the technical, institutional and financial support to create and share resources that are *truly* open. Similarly, some funders (e.g., Achieving the Dream), stipulate that the open textbooks they fund can be retained, reused, revised, remixed and redistributed (5R framework), while others merely care that these resources are free to be accessed online,' or 'free for students.'

From a technical and formatting perspective, there is huge variability as well. Since there really isn't agreed-upon definition of what constitutes an 'open textbook,' one can find open textbooks that are as simple as a PDF posted online, or as complex as a Jupyter Notebook, a web-based application that allows the sharing of documents containing text, live code, equations, and interactive visualizations. Although PDF remains one of the most popular open textbook formats, they are not editable in general, and thus hard to remix. Notebooks, on the other hand, while highly malleable, have a relatively steep learning curve and are – currently at least – only really useful in a handful of disciplines, such as data science, computational informatics, and computer science.

Moreover, we see different concerns (i.e., problems) emerging around open textbooks in different disciplines and, naturally, different solutions or workarounds being proposed. In art history, for instance, there is some concern about the lack of a strong, authoritative voice when a big-name survey textbook like *Stokstad's Art History* and *Gardner's Art Through the Ages* is replaced with a textbook written by a 'no-name' at a small institution, or a collection of OER from around the web. At the same time, image copyright can be a problem for instructors looking to create high-quality, open educational materials. As a result, many art instructors resort to creating resources that are only shared with their students and that are inaccessible to the rest of the world, through for instance their course's learning management system (LMS). In STEM fields like mathematics, on the other hand, there has historically been a large reliance on *test banks*, homework problems, PowerPoints, notes, and practice exams provided by traditional publishers. Because these are typically not provided with open textbooks (or they are insufficient, or their quality is deemed too low), instructors in these fields are more likely to resist open textbook adoption, or to combine them with for-pay services such as adaptive homework systems, which typically cost students $25-50 per semester.

Hard-line advocates of openness raise an eyebrow at such objects and practices, because they 'aren't truly open.' Ultimately, however, most of open textbooks found online – and the practices surrounding them – are 'open' in some ways but not in others.

1.4.1.2. SCOT in educational research: what for?

Educational technology has tended to suffer from an emphasis on - and possibly excessive claims for - technological innovation and novelty (Ferster, 2014; Jones & Bissell, 2011; Watters, 2018). Similarly, educational technology research has tended to advocate the use of technology as a 'transformative' tool that can improve teaching and learning. Overall, technology is seen as a way to 'boost' something – access, student engagement, grades, retention and so on. Most of the research in educational technology asks how we can use technology to make learning more affordable, accessible, or efficient, or how we can use technology to foster collaborative learning in various educational settings. Thus what researchers with an interest in educational technology largely set out to measure is: "How successful has X technology been in achieving Y?"

While this line of inquiry is valuable and important, especially for influencing decisions at the policy level, it also limits how we understand, use and evaluate technology in educational contexts. When we focus on instructional (or institutional) goals and concerns, such as efficiency, the only part made available for technology to play is that of a practical 'tool' serving human activity. Contained by human intention, be it teacher or learner, tools remain a simple extension of the work that people do. Researchers in a range of fields, including science and technology studies, information studies and the media studies have long argued that technology is far from a neutral tool with universal effects (Latour, 1991, 1996; McLuhan, 1967; Pickering, 1995), but instead a medium with complex affordances and constraints, which are distinct from its technological 'features' and the purposes its creators designed it to achieve. Therefore, we cannot merely 'drop' a technology into any classroom like a 'deus ex machina' to improve performance.

As a theoretical and methodological framework, SCOT provides the tools to analyze the integration of information and technology into educational environments without taking its shape and purpose for granted (i.e., in a non-deterministic way). As discussed above, SCOT illustrates how technology creates artifacts which rarely stay in exactly the same form in which they were first created – their developers, their users and other interested 'social groups,' push these artifacts to evolve in new directions. A key strength of SCOT, therefore, is that it provides the conceptual means to open the 'black box' (Pinch & Bijker, p.22) of technology, "thus revealing the multiple social forces that influence and shape the life-course of a technology" (Prell, 2009). SCOT, moreover, allows us to draw a link between technological perceptions and the developmental processes of a technological artifact. While perceptions of faculty, students and administrators are frequently studied in relation to technological 'interventions,' the meaning and implications of those perceptions are usually only discussed in relation to adoption and feature/functionality, i.e., to how likely a user is to adopt a given technology or which features they like/dislike. SCOT, on the other hand, places perceptions in a broader social context.

Few studies so far have applied SCOT to an educational technology context (Jones & Bissell, 2011; Martin, 1999; Prell, 2009; Selwyn, 2011). In this dissertation, I use SCOT to examine how different stakeholder groups interpret 'open' and how their interpretations are shaping the ways that open textbooks are currently implemented in Californian higher education. I show that open textbooks do not transcend along a common path, but take different directions in different markets and contexts. By showing how the meaning (and, shape) of open textbooks remains interpretive, flexible and under constant negotiation both by the people designing and using these artifacts, I provide a counter-narrative to more deterministic views of open textbooks that focus on 'affordances,' 'effects,' and measurable outcomes (e.g., grades, cost-savings). SCOT, moreover, also provides insight into the rise of adaptive courseware and 'personalized' learning platforms that seek to 'augment' or, even, replace textbooks – that is, it allows us to consider how (learning) technology use in higher education is being shaped into an increasingly restricted set of positions by a number of key actors and stakeholder interests.

1.4.2. The material turn in social science: theorizing 'thingness'

> In talking of materiality here, we want to go beyond the brute fact of material forms. That is, what is of interest to us is not simply the fact that apparently abstract and ineffable digital "stuff" actually takes material form; rather, we want to understand the particular material properties of these forms and their consequences for how people encounter, use, and transform them. (Dourish and Mazmanian, 2011, p. 4)

A primary weakness of SCOT is that it goes too far in emphasizing the social and thereby neglects the importance of the physical world and the ways we are constrained by it. In addition, while SCOT provides the theoretical and methodological tools that enable one to analyze the developmental processes and meanings associated with technology, it is not that useful for investigating technology usage, that is how people interact with technology and how these interactions unfold and affect practices and outcomes.

For this reason, in order to complement the analytical framework needed for this dissertation, I now turn to a framing that emerges from a broad set of multidisciplinary works in anthropology, media studies, postmodern literary criticism, information studies and the digital humanities, amongst other, which have emerged in the last decade. These works tend to focus on the materiality, or 'thingness,' of digital artifacts and platforms – literally (e.g., Blanchette, 2011; Kirschenbaum, 2008), discursively (e.g., Barad, 2007; Orlikowski & Scott, 2014), relationally (e.g., Sørensen, 2009) and performatively (e.g., Drucker, 2013). Materiality as a theoretical position seeks to invert the longstanding study of how people make things by asking also how 'things make people,' how objects (such as open textbooks) mediate social relationships—ultimately how inanimate objects can be read as having a form of agency of their own. The material turn's focus on the agency of objects is illustrated through approaches such as Actor-Network-Theory (Latour, 1996; Law, 1992; Law & Hassard, 1999), socio-material 'entanglement' theories (Orlikowski, 2005; 2007); and feminist new materialist approaches to 'material-discursive practices (Haraway, 1988; Harris, 2015). What these approaches have in common, is that they break open the ‘black box’ of technology in order to show how the way that something (such as a system, platform or artifact) is produced, assembled and/or structured conditions its use.

This interest moves beyond notions of ‘historical materialism’ or ‘dialectical materialism’ discussed by the likes of Marx, Engels and Benjamin, which focused on the material forces of history, and the relations between the material world and our ideas about it, respectively (Benjamin, 1935/2008; Carver, 1980; Jennings, 1987; Marx& Engels, 1975; White, 1996). While this earlier reductionist materialism centered only upon macro-structures and super-structures, more recent works on materiality seek to describe how we are *with* and *through* objects, focusing on our relatedness, say, to technological artifacts. In addition, much of this renewed interest in ‘thingness’ has been spurred by widespread, sensational and just plain wrong claims about the ‘immateriality of the digital.’ As technologists and the media prophesized how technologies like the Cloud and virtual reality would ‘liberate’ us from the material plane, more and more scholars began offering correctives that highlight the physicality of the internet and its infrastructure (e.g., Blanchette, 2011; Burrell, 2012; Ceruzzi, 2006; Kisrchenbaum, 2008; Leonard, 2010).

1.4.2.1. Materiality and sociomateriality in educational research

> [C]ontext is critical: learning cannot be considered effectively if the sole focus is upon individual cognitive processing. The content and process of learning change dramatically as it pulses through particular situations and discourses, the tools available, technologies, social relations and environmental dynamics. (Fenwick, 2015)

This section provides an overview of educational perspectives that may be described as ‘materialist’ and situates my own research within ongoing work that draws attention to the material aspects of educational technology and how they shape educational practice. Educational technology research, owing to its focus on measurement outcomes and observable quantities, has only recently focused on materiality. These works have been influenced by a range of theoretical families including Actor-Network Theory (ANT) and sociotechnical studies, complexity theory, new feminist materialisms, poststructural geographies, and others.

Although there are different approaches to and interpretations of 'materiality,' a materialist perspective generally implies that teaching and learning is seen as not only a social process, but also as something material - teaching with and among 'things.' Socio-materialist research emerging predominantly from northern Europe has been concerned with aspects such as space, power/agency, practice and embodiment, illustrating the temporal coexistence and interplay of the material and social, the interface, platform, digital device etc., and the human cognitive-cultural-emotional system that are involved in educational phenomena (e.g. Ceulemans et al., 2012; Fenwick & Edwards, 2011; Mathisen & Nerland, 2012; Roehl, 2012; Sørensen, 2009). These studies demonstrate how materials actively influence learning and teaching practices, how learning itself is a material matter, and how educational processes are in fact socio-material achievements. In doing so, this line of research questions the idea of learning as separate from but taking place in a material and stable context.

Sørensen (2009), for example, draws heavily on geography rooted in Henry Lefebvre (1991) and STS scholars like Donna Haraway (1985, 1988), Bruno Latour (1993, 2005), John Law and Annemarie Mol (1995), to develop a novel spatial approach to the materiality of learning. Sørensen compares an Internet-based 3D virtual environment project in a Danish fourth-grade classroom with the class's work with traditional learning materials, including blackboards, notebooks, and pencils. Drawing on ANT, as well as practice and embodiment theories developed across multiple disciplines, Sørensen seeks to offer an alternative to the mainstream paradigm in educational research where the learning human subject is taken as the foundational object of study, and relations between humans and things are often overlooked. She thus turns away from the participants as individuals (teachers and learners) themselves and follows the process of participation (or performance) instead, attending to how humans and things (blackboard, chairs, virtual learning environment, etc.) take part in educational practice.

Sørensen's overarching goal is to establish a methodology for the study of the 'materiality of learning' that can help us understand how the patterns of relationships among various human and nonhuman participants in learning shape the educational experience. Ultimately, "in order to grasp the materiality of learning", Sørensen argues, "we must describe a particular learning practice as a pattern of relations of human and nonhuman components, and we must characterize the way in which humans are present in this practice" (p. 176). Relationality is key, according to Sørensen, because it is through *the being together of things* that actions identified as learning, become possible. Thus, learning is not just about the relationships between humans (students, teachers, parents, administrators, policy makers etc.), but is instead an effect of assemblages and complex networks between humans and nonhumans. Moreover, teaching and learning do not exist and cannot be conceptualized as separate from the networks through which they are constituted and interpreted, Sørensen argues. Instead of purely individual, cognitive and acquisitive achievements, they are an effect of socio-material practices in which both humans and things partake.

A number of other scholars also draw on aspects of Actor-Network Theory (ANT), specifically posthumanist[2] understandings of agency, in order to highlight the role of nonhuman

[2] Posthumanism is strongly associated with works in cybernetics, artificial intelligence, information systems and science and technology studies. Here I refer to Theodore R. Schatzki's (2001) use of the term, who suggests there are two varieties of posthumanism: one that tries to counter the overemphasis of the subjective or intersubjective that

actants[3] (classrooms, digital devices, software, hardware, textbooks etc.) in the construction of educational phenomena. Fenwick & Edwards (2011) use ANT to highlight the mutual implication of the social and the material in the enactment of educational policy. In particular, the authors argue that ANT sensibilities help to make visible the socio-material assemblages that enact policy, the heterogeneous interactions that form and transform these assemblages, and the multiple ontologies (human and technological) that coexist in policy environments. In their study of teachers' practices with Virtual Learning Environments (VLEs) in Norwegian primary and higher education, Johannesen et al. (2012), use ANT to discuss how VLEs negotiate the socio-material agency of educators and how they shape their teaching practice. Their findings present VLEs as strengthening teaching practice through an entanglement of the social and material in everyday life.

Bolldén (2015a, 2015b) builds on Johannesen et al.'s argument that teacher's agency needs to be understood socio-materially by exploring teacher's embodiment[4] in her study of

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pervades humanism, emphasizing the role of the nonhuman agents, whether they be animals and plants, or computers or other things, and one that prioritizes practices, especially social practices, over individuals (or individual subjects). While both forms or aspects of posthumanism are relevant to this paper, it is the former that I am primarily concerned with and that I am referring to here.

[3] ANT scholars often use the word 'actant' rather than 'actor,' in order to overcome the human connotations of the latter word. In short, an actant is a material entity or human person or group that takes on the shape they do by their relations to other entities such as a user, an information system or a policy maker. While the concept suggests that there is no difference in the ability of technology, humans, animals, or things to act, there is no teleology here that suggests that rocks have goals and desires. Simply put, in order for something or someone to function as an actant, it must somehow modify the action of another entity within the network of relations. A bottle of vinegar is not an actant, however, vinegar mixed with baking soda is because it causes baking soda to behave in ways that it otherwise wouldn't. In relation to the subject of this article and educational technology more broadly, one may say that as long as a technology enables or constraints, it is an actant. See Latour's *The Politics of Nature* (2009) for a more detailed discussion of 'actant.'

[4] Embodiment refers to the bodily aspects of human subjectivity or to the experience of living in, perceiving, and experiencing the world from the physical and material place of our bodies. Over the past thirty years the concept of embodiment has been used extensively in the cognitive science, AI (Artificial Intelligence) and HCI (Human-computer interaction) literature, in such terms as embodied mind (e.g. Gover, 1996; Rosch et al., 1991), embodied intelligence (e.g. Hara & Pfeifer, 2011) embodied cognition (e.g. Clark, 1999; Wilson, 2002) and embodied AI (e.g. Franklin, 1997; Ziemke, 2004). Embodiment is among the core ideas that distinguish recent work on situated

online Swedish higher education settings. Bolldén uses practice theory[5] to analyze how teachers step into an embodied presence online and how they use their embodiments and bodily traces online in order to sustain presence and to bring about certain teaching practices. Her work demonstrates how, when combining a socio-material and practice theory perspective, one may come to see the practice of online teaching as a co-constitution of teachers' 'doings and sayings' and material arrangements in terms of online settings, treated as virtual material. Ultimately, the main premise of these works, is that there are no clear, inherent distinctions between social phenomena and materiality, that knowledge (and *knowing*) is materiality mediated, and that new technologies introduced in the classroom will create, shape and present knowledge in new ways.

Meanwhile, in the US context, Monahan (2008) takes a unique approach to documenting the material information technology infrastructure of public education in Los Angeles; in this framing, infrastructure refers "to the technological assemblage required for Internet access (e.g., computers, software, cables, switches, hubs, electrical outlets, security systems, air-conditioning systems, furniture, and so on) and implicitly to the social components necessary for those systems to 'work' (e.g., funding, policies, curricula, incentives, training, technical staff, contractors, etc." (p. 89-90). Using participant observation at public schools under construction, semi-structured interviews, attendance at board and committee meetings, and physically

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(Haraway, 1988) and distributed (Hutchins, 1995) theories of cognition, from the classical cognitive science approach which was rooted in functionalism and had its focus on 'disembodied' computation (Ziemke, 2004).

[5] Practice theory is not a homogeneous perspective but consists of a body of highly diverse writings by scholars who adopt a loosely defined 'practice approach.' Schatzki (2001) distinguishes four main types of practice theorists: philosophers (such as Wittgenstein, Dreyfus and Taylor), social theorists (such as Bourdieu and Giddens), cultural theorists (such as Foucault and Lyotard) and theorists of science and technology (such as Latour and Pickering). Practice theory stands opposed to prominent modes of thought such as individualism, intellectualism, structuralism, systems theory, and many strains of humanism. Rather than locating the social in the mind of the individual or in interactions between humans, practice theory locates the social in 'practices', where things (artifacts, objects, technologies) and their use are of central concern. For more on practice theory see Reckwitz (2002) or Schatzki et al. (2001). For more on the application of practice theory in education research see Bolldén (2015), in particular Chapter 3.

shadowing “buildings and school sites as newer technological systems are integrated with them” the author illustrates the messy, unfinished, uneven and problematic terrain of technological infrastructure in schools.

Despite the multiplicity of approaches to conceptualizing ‘materiality’ and the absence of a single, unifying definition, as a theoretical tool materiality can offer a broadened understanding of technology and its relation to education, and help us move beyond the types of universalized, decontextualized visions of technology that have dominated research on learning in education, psychology, sociology and cognitive science. Rather than treating technology as a mere instrument for human purposes, it provides an avenue to understand it as an active participant that co-constructs experiences, knowledge and ideologies in the classroom. This is not to say that humans and technological artifacts are the same, or equal in the construction of social phenomena, but rather that there is a bidirectional relationship taking place that needs to be better understood. However, in contrast to posthumanist accounts of education (e.g. Sørensen, 2009), in this dissertation, I use the lens of materiality to analyze open textbooks as products of both material and social forces, as well as to highlight human practices vis-à-vis material objects.

1.4.3. Infrastructure from a social science lens

> ‘Infrastructure’ is a most unglamorous term, the type of word that would have vanished from our lexicon long ago if it didn’t point to something of immense social importance. (Russell & Vinsel, 2016)
>
> The best […] conversations about infrastructure move away from narrow technical matters to engage deeper moral implications. Infrastructure failures – train crashes, bridge failures, urban flooding, and so on – are manifestations of and allegories for America’s dysfunctional political system, its frayed social safety net, and its enduring fascination with flashy, shiny, trivial things. (Russell & Vinsel, 2016)
>
> With infrastructure, then, there can be no simple distinctions of science, technology, values, society and political power, since they all interpenetrate one another and occur synchronously (Slota & Bowker, 2017)

The heuristic frameworks of social construction of technology and materiality can be extended by adding theory from infrastructure studies as an additional perspective. Materiality and infrastructure studies both form part of a critical-material turn in social and behavioral sciences, a growing recognition of the “the importance of artifacts, natural forces, and material regimes to social practices and systems of power” (Mukerji, 2015).

The term ‘infrastructure’ is defined in the Oxford English Dictionary as “...the subordinate parts of an undertaking; substructure, foundation; spec. the permanent installations forming a basis for military operations, as airfields, naval bases, training establishments, etc.” In the 1950s and 60s, it gained popularity in economics and planning, where it refers to capital investments that facilitate directly productive economic activity or development (Baldwin & Dixon, 2008). In vernacular usage, infrastructure often refers to artifacts built of concrete and steel: the ‘hard’ technical systems that facilitate the distribution of people, energy, water, waste, information, and so on. However, the use of the term has expanded rapidly in recent decades as it has been deployed in a variety of new fields.

Broadly speaking, studies on infrastructure have tended to focus on analyzing essential, widely shared socio-technical systems. Using case studies ranging from electric power grids (Hughes, 1983), to airports (Hirsch, 2016) to communication networks (Graham and Marvin, 2001), these works have highlighted key features of infrastructure such as ubiquity, reliability, invisibility, gateways, and breakdown. A second intellectual stream in infrastructure studies, has highlighted the phenomenology and sociology of infrastructure (Bishop et al., 2000; Borgman et al., 2013; Bowker et al., 2009; Dourish & Bell, 2007; Edwards, 2003; Edwards et al., 2009; Jackson et al., 2007; Star, 1999) These studies conceptualize infrastructure in ways that bridge these macro-scale studies and the actor/artifact - centered approaches advocated in SCOT (Bijker et al., 1987) and ANT (Bruni & Teli, 2007; Latour, 1983; 1996; Law, 2008), which I discussed above. While the large technical systems approach tends to emphasize top-down, unified organization by system builders, the approach espoused by scholars like Bowker & Star (2000; 2006) is less hierarchical. Infrastructures are conceptualized ecologically, which is to say that they are understood to come into being, persist, and fail in relation to the practices of the diverse communities that accrete around them (Star and Ruhleder, 1996). As a result, this approach also emphasizes the human dimension of infrastructure, "such as work practices, individual habits, and organizational culture" (Plantin et al., 2018, p. 296).

Larkin (2013) defines infrastructures as "matter that enable the movement of other matter;" "what distinguishes infrastructures from technologies," he argues, "is that they are objects that create the grounds on which other objects operate, and when they do so, they operate as systems" (2013, p. 329). Star, who pioneered the studies of infrastructure within STS, argued that infrastructure is what is taken for granted in the accomplishment of tasks; it is therefore perspectival (in the sense that what counts as infrastructure depends on who you ask), fragile, held together by invisible labor, and becomes visible when it breaks down (Jackson, 2014; Star, 1999). Importantly, infrastructural assemblages "evolve and mutate as new ideas and knowledges emerge, technologies are invented, organizations change, business models are created, the political economy alters regulations and laws are introduced and repealed, skill sets develop, debates take place, and markets grow or shrink" (Kitchin & Lauriault, 2014, p.7). Thus, when dealing with infrastructures, we need to look to the whole array of organizational forms, practices, and institutions which accompany, make possible, and inflect the development of new technology.

To study infrastructure through a social science lens, Bowker and Star (2000) suggest using the methodological approach of "infrastructural inversion," (Star & Ruhleder, 1996, p. 113) which calls attention to the practices that support an infrastructure, rather than the activities the infrastructure makes possible. For example, in the case of Ribes (2014), a close look at the computational infrastructure for the Large Hadron Collider revealed the hidden work—deploying, rejecting, and combining different tools and metrics—required to assess a system's ability to scale to support cutting edge particle physics research. While the Large Hadron Collider and the research it supports typically takes center stage, infrastructural inversion revealed the multitude. A focus on practices reveals elements of the infrastructure that we miss by examining infrastructure as an object (Star & Ruhleder, 1996).

Three elements of infrastructural inversion in particular offer promising complements to the dominant modes of studying open textbooks: a focus on how systems change (in contrast to studying ways that systems change the world around them); a focus on maintenance work (in contrast to studying initial design); and a focus on how systems are embedded within and interdependent with other systems (in contrast to studying a system in isolation) (Star & Ruhleder, 1996). Chapter 5 illustrates these points through a case study of OpenStax, an open textbook provider based out of Rice university in Houston, Texas.

1.4.4. Theoretical contributions of this dissertation

Relying on socio-technical approaches to educational technology research and conceptual frameworks developed in Science and Technology Studies (STS) and related disciplines (e.g., Information Studies, Infrastructure Studies), this project considers the production and use of open textbooks as a sociotechnical process. The analysis in the ensuing chapters of this dissertation brings into view the infrastructural basis, the ideological underpinnings, the specific technological affordances/constraints, and the socio-material practices surrounding open textbooks.

First, by engaging with concepts from the social construction of technology, I uncover the multiple perspectives that frame the design and appropriation of open textbooks. I examine the public discourse around open textbooks, the priorities of different stakeholders, and how their various readings and understandings of 'openness' are shaping the production and implementation of these resources. Drawing on multiple sources, I demonstrate that understandings of what open textbooks are, what they mean, and what they should look like, differ starkly across markets, types of institutions, and user groups. In fact, when I describe open textbooks as seen through the eyes of different stakeholders, we see different technologies emerge and try and solve similar problems from different angles. I thus demonstrate the 'interpretive flexibility' of open textbooks: there is not one open textbook that follows its 'natural' path, but multiple ones competing to become the standard. As I discuss, the discrepant interpretations of relevant groups inevitably create a natural tension in the development and deployment efforts because of differences in expectations. Also, because open textbooks are relatively new and still changing, the technological frameworks of end users appear to be evolving and there are not yet any significant alignments among different frames.

Second, my investigation adds a critical lens to the popular – within the open community – view of system modularity as a driver for customization, personalization and pedagogical innovation. I use a case study of a major open textbook provider to trace the evolutionary path of open textbooks over twenty years and analyze how modularity has been reframed and repositioned from enabler of pedagogical freedom to enabler of modular business processes and networks based largely on market forces and consumer choices. I show that, while open advocates were trying to drive change by focusing on the modularity of open textbooks and their capacity to be appropriated, remixed and so on, instructors were resistant to modifying their existing practices. The open community thus built a solution based on a perceived problem (the irrelevance and outdatedness of traditional, print textbooks); but because instructors did not observe the same problem that needed to be fixed (at least, not to the degree that the open community did), they were reluctant to adopt open practices and modify their teaching approach. As a result, we are seeing open textbooks today starkly resemble the very objects they were trying to displace. My analysis also brings a systems perspective into closer dialogue with analysis of labor forms and processes and accompanying materialities of open textbook development, distribution and maintenance. The analysis provides insight into open textbook modification and remix practices, as well as the evolutionary path of open textbooks given their technical and market structure.

Third, I investigate issues of materiality related to the use of open textbooks to dispute persistent narratives about the so-called immateriality of new educational technologies and to complicate the virtue of paperlessness espoused by educational technology providers and open advocates. In particular, my discussion highlights the durability of paper and paper practices within an increasingly digital environment, cutting through the so-called dichotomy between paper and electronics that dominates popular discourse, as well as much of the research in educational technology on ebooks, e-readers and digital courseware. I demonstrate that the relationship between print and digital is a lot more fluid, dynamic and 'symbiotic' than is often believed and indicative of a growing desire for multimedial and (truly) personalized learning experiences. My study extends the work of Sellen & Harper (2002), who examined the myth of the paperless office, by analyzing the trope of 'paperlessness' in the open textbook context through classroom observations and historical analysis.

This project complements emerging research into open textbooks/OER and continuing research into access and equity in educational technology by addressing these efforts beyond the question of their potential instrumental value in higher-ed. This research also expands our empirical understanding of how openness is imagined, practiced and negotiated in the state of California.

1.5. Dissertation structure

The organization of this dissertation emphasizes the three lenses I bring to understanding the open textbook phenomenon, namely that of social construction, of systems thinking and of materiality (and, to a lesser degree, that of media history and archaeology). Together they contribute to the understanding of the different dimensions that frame the open textbook phenomenon as it is in the process of transforming.

Chapter 1 outlines the theoretical basis from which the subsequent research presented in this dissertation can be understood. I start out by offering an overview of 'social shaping' approaches to the study of technological artifacts, focusing specifically on the Social Construction of Technology (SCOT). I then provide a review of emerging literature at the intersection of education and Science and Technology Studies (STS), which uses materialist and posthumanist approaches to challenge the dominance of the humanist subject in educational - and educational technology - research. I argue that a focus on materiality allows us to describe open textbooks as the (highly) diverse and complex computing objects that they are, rather than mere neutral 'tools' that carry educational content. I also draw on theoretical works on infrastructure, particularly works that address infrastructure within the framework of a critical-material turn in social and behavioral sciences, to discuss the importance of conceptualizing open textbooks in terms of the systems, artifacts, people and relations needed to implement them. My goal is to show how a theoretical framing sensitive to materiality and infrastructure helps us open the 'black box of technology', and better understand how open textbooks are shaped by the technical infrastructure underlying their interface, as well as the social groups that design, produce and use them.

Chapter 2 provides a brief history of open textbooks, along with a review of the existing literature on open textbooks. It also provides an overview of my methods and methodology. I begin by tracing the origins of open textbooks in the open-source movement of the late 90s, and by describing how open textbooks have evolved both in shape and in meaning over time, from 'learning objects' to 'open educational resources' and into the 'open textbooks' of today. I also note the fluidity of definitions and perceptions in terms of what really constitutes an 'open textbook' and the tension between proponents of 'affordable' versus 'open' educational materials, before offering a working definition of these objects for the purpose of this dissertation. I then review and identify gaps in the existing literature on open textbooks, and situate my study against a backdrop of survey-heavy research that focuses on attitudes and student retention/grades. In the second half of the chapter, I discuss and justify my methods, and describe my informants and research sites. I discuss my selection of open textbook platforms and sites for my participant observation, and acknowledge some of the intentions and problems behind these decisions. I also discuss how I analyzed and interpreted the data I use.

Chapter 3 builds on the discussion in Chapter 2 by situating open textbooks within a longer history of openness and educational technology in the classroom. By charting the history of open education from the Middle Ages, to 17th century coffee houses, to open universities and through the open source and free software movements of the 1980s and 1990s, it provides a basis for understanding how notions of openness in relation to learning have evolved over time. Moreover, the chapter discusses some of the challenges and shortcomings of earlier 'incarnations' of open education, like Learning Objects and MOOCs, and underscores links to technical, pedagogical and economic issues that also plague the open textbook phenomenon. Finally, the chapter examnes contemporary discourses around open education, offering a critical commentary on the perception of openness as both a disruptive force in education, and a potential solution to contemporary challenges – i.e., rising tuition costs, low completion rates and lack of student engagement.

Chapter 4 is the first of the three analysis chapters and demonstrates the socially constructed character of open textbooks. In particular, I analyze the public discourse around open textbooks, the priorities of different stakeholder groups, and how their various understandings of 'openness' (and its significance) are shaping the production and implementation of open textbooks. In my analysis, I draw on interviews with key stakeholders and promotional material from the leading open textbook providers to discuss how starkly understandings of what open textbooks are, what they mean, and what they should look like, differs across types of institutions, markets and user groups. I also discuss how these underlying assumptions about the meaning and function of open textbooks shapes their design, production processes, and the material formats in which they are delivered and consumed, all of which in turn shape how these technological artifacts work pedagogically, both in the classroom and outside it. The chapter also addresses concerns about traditional publishers and other for-profit companies 'hijacking' the open textbook movement through 'affordable' subscription models and value-added services, the attitudes of various stakeholders toward them, as well as some of the actions being taken to circumvent them.

In Chapter 5, my analysis zooms in one particular open textbook provider, namely OpenStax. I take a systems approach to analyze the movement of OpenStax content — from production and circulation to consumption — and its structuration through social and technical infrastructures to identify the points at which movement is constrained. By following the sociotechnical processes involved in the production, circulation, consumption and maintenance of OpenStax content, this analysis emphasizes the dynamic interplay between organizations, vendors, technologies and individuals involved in open textbook implementation; the tensions between different systems and sub-systems that create, 'absorb' and modify open textbook content; and the invisible labor of formatting, maintenance and repair that goes into 'doing' open textbooks. In addition, the chapter analyzes some of the new institutional and market structures that open textbooks make possible.

In Chapter 6, I examine the role that print and paper play in the way that open textbook are implemented and used. I describe the contested relationship between paper and digital formats, and challenge the claim that 'the future of textbooks is digital' and divorced from the 'mundane' and 'old-school' materiality of the printed text. I draw on my interview data to discuss attitudes toward print, and on classroom and conference observations to highlight the endurance of paper in the college classroom. I argue that the relationship between print and digital is a lot more fluid, dynamic and 'symbiotic' than technology pundits and certain open textbook providers would have us believe, and indicative of a growing desire for multimedial and personalized learning experiences.

In the final conclusion (Chapter 7), I review how the various chapters have worked together as a cohesive critique of open textbooks, and emphasize the overall contribution of this dissertation. I also offer suggestions for open textbook implementation and pedagogy, consider the limitations of my methods and the data I use, and specify areas where work in this dissertation could be productively developed into future research.

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CHAPTER 2: BACKGROUND ON OPEN TEXTBOOKS AND RESEARCH METHODS

2.1. Introduction

This chapter is divided into two sections. The first part provides some background on open textbooks, along with a survey of existing literature in the field. The literature review focuses on areas of interest for this research project: open educational resources (OER), open textbooks and open practices. Although the focus of this research is open textbooks, some general information about open education and open educational resources is included to better describe the context around open textbooks. The second half of the chapter provides an overview of my methods and methodology. I discuss and justify my methods, and describe my informants and research sites. I discuss my selection of open textbook platforms and sites for my participant observation, and acknowledge some of the intentions and problems behind these decisions. I also discuss how I analyzed and interpreted the data I use.

2.2. A (brief)[6] history of open textbooks

Open textbooks are a form of open educational resource (OER) and cannot be discussed in isolation from the OER movement of the past 20 years. The birth of OER can be traced back to the early 1990s when the term 'learning object' emerged to refer to small-sized, highly-modular and reusable instructional components, designed for distribution over the Internet (Downes, 2001; Friesen, 2005; Wiley, 2002). While the concept of learning objects has lost traction in

[6] For a more extensive discussion on the history of open education and OER see Chapter 3.

recent years, it popularized two ideas that remain at the very heart of the OER and open textbook movements. One relates to the belief that digital learning materials should be designed and produced in such a manner as to be reused easily in a variety of pedagogical contexts and disciplinary perspectives. The second, is the idea that knowledge (i.e., educational content) is best broken down into discrete elements or building blocks that can then be reassembled in endless combinations to meet the needs of diverse students and institutional contexts. Along with its emphasis on modularity, remix and reuse, the learning object movement spawned several standards efforts aimed at detailing metadata, content exchange, and other standards necessary for users to find and reuse digital educational content.

Spurred by the interest in learning objects, the California State University created MERLOT in 1997. MERLOT is a repository and international cooperative of institutions seeking to provide access to online educational materials open for others to use. Soon after, in 1998, David Wiley, then an assistant professor at Utah State University, coined the term 'open content,' suggesting that the principles of the open source and free software movements could be productively applied to educational content. Wiley also proposed the creation of the first widely adopted license for free and open content, the Open Publication License.

Simultaneously, the open access[7] movement was growing from a tiny beginning in 1993 to the publication of PLOS in 2001 and the Budapest Open Access Initiative in 2002, which helped establish open access as a world-wide approach to sharing research. Around that time, Lawrence Lessig and a group of other open content activists founded Creative Commons (CC), which released a set of flexible public licenses to share digital content. These easy-to-use

[7] Refers to the practice of making peer-reviewed scholarly research and literature freely available online to anyone interested in reading it.

licenses allowed individuals and institutions to maintain ownership of their creative products (photos, films, websites, documents etc.) while giving others selected rights. These rights range from allowing use of a work in its existing form for noncommercial purposes to the right to repurpose, remix, and redistribute for any purpose. The release of the CC licenses was instrumental to the growth of the OER movement, because it increased the credibility of these resources, as well as confidence in their legal authority.

The idea of open content (and courseware) achieved much greater visibility when MIT announced (on the front page of the New York Times) its OpenCourseWare (OCW) initiative in 2001 with the goal of publishing nearly every university course for free public access for noncommercial use. While OCW has had a more direct influence on the development of the MOOC than the OER movement, it has certainly inspired the institutionalization of openness, including OER and open textbooks.

As a term, OER was first used at UNESCO's 2002 Forum on 'The Impact of Open Courseware for Higher Education in Developing Countries,' which was funded by the William and Flora Hewlett Foundation, and brought together actors who declared their wish to "develop together a universal educational resource available for the whole of humanity" (UNESCO, 2002). According to this forum, OER was to refer to openly accessible, editable, downloadable curriculum resources for instructors and learners across the globe. These resources included course materials, modules, streaming videos, tests, software, and any other tools, materials or techniques used to support access to knowledge. Over time the term has come to cover not only content, but also learning and content management software and content development tools, and standards and licensing tools for publishing digital resources, which allow users to adapt resources in accordance with their cultural, curricular and pedagogical requirements (OECD, 2007, p.31).

In recent years, largely driven by institutional needs and market forces, open textbooks emerged as packaged sets of OERs and wholly-commissioned works to replace the proprietary, copyrighted works of the traditional textbook publishers. While not completely different from OERs, they are no longer considered supplementary resources, but instead represent an organized attempt to create a complete set of materials and learning content for the scope of an entire course.

A turning point for open textbooks was the year 2012, also known as the "Year of the MOOC" (Pappano, 2012), when interest in open education was at its peak, and when OpenStax released its first peer-reviewed open textbook, *College Physics*. Founded as Connexions (CNX) in 1999 by electrical engineering professor Richard Baraniuk, OpenStax started as an OER repository where faculty could publish, share, and remix educational materials. Initially a big proponent of highly granular content objects, OpenStax ultimately shifted to publishing traditional-looking open textbooks, after realizing that the majority of instructors preferred 'readymade' textbooks that they could use 'as is,' instead of having to pull together chunks of content from all over the web. Since publishing *College Physics (*online, in print, and in iBooks), OpenStax has added numerous other intro-level courses to their catalogue, including *Anatomy*, *Astronomy*, *Microbiology* and *US History*, becoming the largest non-profit open textbook publisher in the US. Other institutions followed Rice's lead, including the State University of New York, Tidewater Community College in Virginia and the University of Maryland University College.

Broadly speaking, the first decade of open textbooks was focused on creating content and getting it online under a Creative Commons license. Platforms such as California's MERLOT system, Open Oregon, Open SUNY Textbooks, Rice University's OpenStax and The University of Minnesota's Open Textbook Library emerged to support the creation and storage of openly-licensed digital textbooks. Now that a lot more material is out there and searchable, the focus has shifted from creation to institutionalization and scaling up. Over the past few years, an entire ecosystem of services has emerged to support institutions and instructors as they implement open textbooks, including but not limited to adaptive courseware platforms (e.g., OpenStax Tutor, RealizeIt, Lumen Learning), digital homework systems (e.g., HYZ Homework), social learning platforms (e.g., Perusall), and publishing and mentoring services (e.g., SUNY OER Services, Rebus Community Projects).

The development of this ecosystem also suggests a move away from the idea of the 'textbook' to intelligent learning software and systems that offer customizable services to the teacher and learner. This shift away from mere content creation to the development of an infrastructure that can support open educational practices long term, is also reflected in the revised funding priorities of foundations such as the Hewlett and Gates foundations, who are increasingly providing grants for infrastructure purposes (e.g., technology and technical infrastructure, marketing and communication for OER, general support for 'anchor' institutions).

Another recent and significant development in the OER/open textbook arena has been the spread of OER and Zero Textbook Cost (ZTC) degrees across the country. These degree programs, based entirely on OER and other free digital materials, are becoming a major mechanism for using digital tools to address issues of equity across the country, particularly at community colleges, which tend to serve student populations from lower income backgrounds, for whom the high cost of textbooks is particularly inhibiting. As of 2018, almost 40 new OER degree programs were being established around the country.

2.3. Open textbooks in California higher education

In California, interest in OER and open textbooks is a relatively new phenomenon, at least at the state and institutional levels (as opposed to, say, the individual and departmental).

California's higher education system includes three public segments—the University of California (UC), the California State University (CSU), and the California Community Colleges (CCC) – which enroll nearly 3 million undergraduate students and employ almost 100,000 faculty. In addition to being one of the largest in the country, the public higher education system in California represent one of the most diverse—racially, ethnically, and economically—student bodies in the nation: Latinos account for one-third of CSU's undergraduates, while the state's community colleges harbor an even more diverse, predominantly working-class student body (Hanley & Bonilla, 2016).

In recent years, though, multimillion-dollar cuts in state funding have led to soaring tuition – from 2004 to 2017 the average in-state tuition at the UC has increased from around $4,000 to over $12,000. As institutions increasingly shifted higher education costs to students and their families, already burdened by recession-induced unemployment, growing debt, and skyrocketing rent and housing prices, the California public higher education system was rapidly swept into the 'affordability crisis' that has come to define US higher education over the past decade (Hanley & Bonilla, 2016).

In 2012, in response to concerns about rising inequality in access to higher education in the state, the California State Legislature passed bills SB 1052 and SB 1053, which aimed to reduce the “skyrocket[ing]” costs of attending California’s public colleges and universities through provision of open textbooks and other OER materials (Abraham, 2012). SB 1052 authorized the creation of an OER Council composed of three faculty members from each of California’s three higher education segments with the goal of identifying OER materials for 50 high impact courses across UC, CSU, and CCCs. For this purpose, SB1052 provided $5 million for three years, a sum that was supplemented by grants (secured by the CSU administration) from the Hewlett and Gates foundations. SB 1053 established the California Digital Open Source Library (COOL4ED), a statewide online repository for OER currently maintained by the CSU. The council disbanded in May 2016.

A few years later, in 2015, Assembly Bill 798 was passed. Also known as the “College Textbook Affordability Act”, the bill provided $3 million for the CSU and CCC to support faculty adoption of free and open educational resources that reduces cost at least 30%. Specifically, AB 798 established the OER Adoption Incentive Fund to financially support professional development programs for faculty to modify curriculum to include OER and other low-cost educational materials. At the CSU, the bill complemented the work of Affordable Learning Solutions (ALS), a CSU initiative launched in 2010 to “support and encourage campus faculty to consider using high-quality, low cost or no cost, accessible textbook alternatives” (ALS, n.d.).

As interest in entire OER and Zero Textbook Cost (ZTC) degrees nationwide began to grow, Governor Jerry Brown announced in 2016 that California would be making $5 million available in direct grant funds specifically to establish ZTC degree programs at the individual community college district level, with grants of up to $200,000 for each participating college. The California Community Colleges Chancellor's Office defines a ZTC program as "a community college associate degree or career technical education certificate earned entirely by completing courses with no cost textbooks. The program uses alternative instructional materials and methodologies, including educational resources." (CCCCO, n.d.). It is important to note that these grants do not exclusively support the adoption of open textbooks, but any educational resource that is free to students, including library resources and web-pages that are free to access, but not necessarily openly licensed. As of 2018, 20 California Communities are working on the implementation of ZTC degrees (Phase II of the grant)[8]. In addition to the ZTC degree grants provided by the state, a handful of community colleges in California (Santa Ana College, West Hills College Lemoore) have received support from the non-profit Achieving the Dream in order to implement OER degrees on their campuses. Contrary to the 'looser' ZTC degree funding stipulations, Achieving the Dream expressly requires institutions to design pathways using only open educational resources.

Finally, it should be noted that the UC (University of California) system has largely remained on the periphery of the open textbook movement. While most UC libraries house some sort of "Affordable Course Materials" initiative (similar to CSU's ALS initiative), there is no large-scale institutional effort to increase OER and/or open textbook adoption on UC campuses. Meanwhile the CSU has taken a 'hybrid' approach to OER implementation pretty much from the get-go. In other words, relying exclusively on OER (such as open textbooks) was never seen as a viable solution. Instead CSU has opted to collaborate with a number of ed-tech companies over the years in order to provide 'innovative' and 'affordable' learning solutions to their students,

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[8] See http://extranet.cccco.edu/Portals/1/AA/OER/2017-18/17-085%20IntentToAward1.pdf

including in the past Apple, and more recently Top Hat Marketplace, a for-pay platform which includes OER and original content instructors can customize, along with homework resources and assessments.

2.4. Definitions of key concepts

2.4.1. Open education

Open education is notoriously difficult to define because of its vague nature and the fact that it means different things to different people in different contexts (Weller, 2014). As Cronin (2017) points out, ‘open’ is variously used to describe resources (the artefacts themselves as well as access to and usage of them), learning and teaching practices, institutional practices, the use of educational technologies, and the values underlying educational endeavors. According to Wiley (2012), “open education is the umbrella term that covers everything we're doing with openness as a lever to try to expand access to educational opportunity to the entire world. OER are part of it; open teaching is part of it, open access is to research part of it, open assessment is part of it, open badges and other open credentials are part of it, open policies are part of it, etc.”

At its core, ‘open’ is a philosophy about the way people should produce, share, and build on knowledge, the idea being that human knowledge can only grow through free sharing and collaboration. Thus, open education is not limited to just creating and using resources (e.g., open textbooks) but involves aspects like opening up relevant educational data; utilizing open technologies that facilitate collaborative, flexible learning and the open sharing of teaching practices that empower educators to benefit from the best ideas of their colleagues; and changing both institutional and wider culture (Cape Town Open Education Declaration, 2007).

However, in the United States, ‘open education’ is still too often conflated with ‘openly licensed materials’ or ‘open content.’ Of course, open licensing is incredibly important for access and distribution and remixing. As Watters (n.d.) has argued, open licenses are important in pushing back on assumptions of ‘ownership’ around educational content and data — that is, thinking about copyright and Creative Commons can prompt an important discussion about what happens to the content and data created by teachers and students alike.

But when we frame ‘open’ only in terms of licenses and permissions, we run into the problem of conceptualizing openness as a binary between ‘open’ and ‘closed,’ one that hardly reflects the nuance, diversity and contradictions of people’s on-the-ground perspectives and practices, as this dissertation illustrates. Part of the problem, is that mainstream educational narratives have largely framed OER as a fix for cost and access issues, which in terms limits how these objects and their potential is perceived. Thus, the challenge over the next few years will be to move beyond thinking about ‘open’ as a way to save student money, toward a more critical and holistic view which treats it as an ethos and a set of activities that might also help transform how we teach, how we learn and how we engage with information more broadly.

2.4.2. Open educational practices

Scholars interested in this shift away from ‘content’ toward ‘process’ are increasingly talking about open educational practices (e.g., Andrade et al., 2011; Campbell, 2012; Cronin, 2017; 2018; Ehlers, 2011; Knox, 2013; Stagg, 2014; Tuomi, 2006; Weller, 2014; Wiley & Hilton III, 2009) which they view as a way to “broaden access to education and knowledge, reduce costs, enhance the impact and reach of scholarship and education, and foster the development of more

equitable, effective, efficient, and transparent scholarly and educational processes" (Veletsianos & Kimmons, 2012, p 166). Elsewhere it has been argued that practices instead of resources is a more useful way of conceptualizing openness overall (Murphy, 2013; Smith & Seward, 2017). However, what exactly we mean by 'open educational practices' is an open debate. Generally speaking, collaborative writing, peer reviewing of teaching materials, open assessment, collaborative homework assignments, feedback through learning analytics, and the remixing and repurposing of open content have all been identified as open educational practices.
Below are some common definitions of OEP:

- *"Open Educational Practices are defined as the use of open educational resources in such a way that the quality of educational experience is raised." (Ehlers & Conole, 2010)*
- *"Open Educational Practices are teaching techniques that draw upon open technologies and high-quality Open Educational Resources (OER) in order to facilitate collaborative and flexible learning." (COERLL, n.d.)*
- *"[Open educational practices is] the use of Open Educational Resources to raise the quality of education and training and innovate educational practices on institutional, professional and individual level." (OPAL, 2012)*

What all of these definitions have in common, is that they essentially take "practice" to mean "pedagogical" or "teaching" practice, which traditional refers to curriculum planning and instructional methods, and which is a pretty narrow interpretation of the term. They also largely focus on the use or development of OER resources, which brings us back to the fixation with content, versus how people interact with that content. This interpretation is not all that surprising, however, given that “open educational practices” and “open pedagogy” are often used interchangeably within the educational community.

The International Council for Open and Distance Education (ICDE) takes a broader definition of OEP, stating that they are “practices which support the production, use and reuse of high quality open educational resources (OER) through institutional policies, which promote innovative pedagogical models, and respect and empower learners as co-producers on their lifelong learning path.” (ICDE, n.d.) While this definition is more encompassing, it retains focus on the ‘happenings’ in the classroom and the transmission of content to the learner, instead of the ‘doings’ of the teacher ‘with’ the technology. For the purpose of this study, open educational practices are defined as the set of pedagogical, professional, technical, administrative and academic activities that instructors engage with as they ‘do’ open textbooks, including but not limited to the co-creation, remixing and redistribution of these resources.

2.4.3. Open textbooks

As mentioned earlier, open textbooks are a type of open educational resource. The definition of open, as well as the meanings of the terms open education, and OER still vary (Cronin, 2017; Mulder, 2007; Rumble, 1989; Weller, 2014; Wiley et al., 2013). The same issues arise when discussing open textbooks as well. Open textbooks are a type of open (educational) content. Open content – be it textbooks or other resources like course materials, modules and tests – is usually defined in terms of the rights granted by the creator to the user. According to Wiley (n.d.), the term ‘open content’ describes any “copyrightable work that is licensed in a manner that provides users with free and perpetual permission to engage in the 5R activities”. These include:

1. Retain — the right to make, own, and control copies of the content (e.g., download, duplicate, store, and manage)
2. 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)
3. Revise — the right to adapt, adjust, modify, or alter the content itself (e.g., translate the content into another language)
4. Remix — the right to combine the original or revised content with other open content to create something new (e.g., incorporate the content into a mashup)
5. 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).

However, much of the material now called open textbooks (and OER more broadly) does not meet all of that criteria. Part of that has to do with the nature of Creative Commons licensing itself, which provides room for the author of the educational resource to restrict certain areas of use. For example, CC BY ND is a license that requires all users to acknowledge the author (BY) and not create derivatives (ND). Because it does not allow alteration of content, CC BY ND reduces (in the eyes of the open education community) much of the usefulness of the resource.

In addition, in the United States, the open education and textbook affordability movements have become tightly intertwined. As a result, free but restrictively copyrighted electronic textbooks (i.e., ‘all rights reserved’) are oftentimes referred to as ‘open textbooks,’ especially by practitioners (i.e., faculty). Advocates, on the other hand, would likely argue that deviation from any of the 5Rs reduces the relative ‘openness’ of an educational resource. The many dimensions and expressions of the word ‘open’ as it relates to OER provides an insight into the difficulties the group had in understanding what the combined term ‘open textbooks’ really means. When we add to that the slippery notion of ‘textbook’ in the context of the digital age, defining just what an open textbook is becomes open to discussion.

BCcampus (n.d.) defines open textbooks as, “a textbook licensed under an open copyright license, and made available online to be freely used by students, teachers and members of the public.” The definition is very close to the one offered by ISKME, which defines open textbooks as “textbooks that are free for anyone to use, reuse, and redistribute”. (ISKME, n.d.) Interestingly, permission to adapt and repurpose the educational resource is missing from many stated definitions of open textbooks (and OER more broadly). In addition, some definitions of open textbooks take a broader view to include materials that are low-cost rather than free.

Not all open textbooks look like, well, textbooks. In fact, they come in all shapes and sizes: wikis, PDFs, HTML pages, iPython notebooks, and Word documents to name a few, all with their own specific types of affordances and constraints. Some are monochrome and plain-looking, while others are highly interactive platforms, including videos, simulations, animations and interactive movies. As far as the textbook material is concerned, however, open textbooks do have many similarities with traditional textbooks. The educational content is written by faculty or subject experts, and it aims to cover a similar scope and sequence of topics. Some even come with support materials like online homework, test banks, and supplemental videos.

Because this research project investigates openness *in practice*, it does not rely on a predetermined (or imaginary) definition of ‘open.’ Chapter 4 focuses on how different stakeholders interpret ‘openness,’ and how they think about open textbooks in particular. Chapter 5 is focused on OpenStax, one of the major open textbooks providers in the United States, whose textbooks are licensed under Creative Commons. Chapter 6, meanwhile, draws on classroom observations in two math courses that used free digital texts, one of which is licensed under a Creative Commons ShareAlike License (and thus meets the 'formal' definition of an open text) and the other of which is a copyrighted work (and thus does not fit the formal definition of an open text). Together these chapters capture how openness is actually implemented on the ground, which is on a spectrum rather than along binary lines. Note that the scope of this research study excludes open courses (e.g., Carnegie Mellon's OLI courses and UCI Open), as they are generally geared toward independent and lifelong learners rather than college students.

2.4.4. Open licenses

A key aspect of OER use is the set of rights afforded by open licenses, such as those provided through Creative Commons (CC) licenses. CC licenses extend rights from copyright holders to others in society who would like to make use of existing works such as books, courseware, images, video, animations or other resources that can be freely reused in educational settings. A CC license is used when an author wants to give people the right to share, use, and build upon a work that they have created.

CC licenses have become the de-facto method for providing educational resources in a manner that specifies rights in plain language using one of the Creative Commons licenses. Libraries, OER repositories and open education projects around the world have adopted this licensing model for open courseware, open textbooks, and open access academic journals, to name a few. However not all CC licenses are 'open,' as the table below illustrates. Licenses that do not allow users to create derivative works, such as the CC-BY-ND license, are not fully open.

The following table[9] describes each of the main six licenses offered by CC, from the mots 'open' one (CC-BY), to the most restrictive one (CC-BY-NC-ND):

	CC-BY Attribution – 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, in terms of what others can do with your works licensed under Attribution.
	CC-BY-SA Attribution Share Alike – This license lets others remix, tweak, and build upon your work even for commercial reasons, as long as they credit you and license their new creations under the identical terms. This license is often compared to open source software licenses. All new works based on yours will carry the same license, so any derivatives will also allow commercial use.
	CC-BY-ND Attribution No Derivatives – This license allows for redistribution, commercial and non-commercial, as long as it is passed along unchanged and in whole, with credit to you.
	CC-BY-NC Attribution Non-Commercial – This license lets others remix, tweak, and build upon your work non-commercially, and although their new works must also acknowledge you and be non-commercial, they don't have to license their derivative works on the same terms.
	CC-BY-NC-SA Attribution Non-Commercial Share Alike - 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. Others can download and redistribute your work just like the by-nc-nd license, but they can also translate, make remixes, and produce new stories based on your work. All new work based on yours will carry the same license, so any derivatives will also be non-commercial in nature.
	CC-BY-NC-ND Attribution Non-Commercial No Derivatives - This license is the most restrictive of our six main licenses, allowing redistribution. This license is often called the "free advertising" license because it allows others to download your works and share them with others as long as they mention you and link back to you, but they can't change them in any way or use them commercially.

Generally speaking, the CC-BY license is considered the 'gold standard' for OER. CC-BY allows others to "copy and redistribute the material in any medium or format; to remix,

9 Adapted from: https://creativecommons.org/licenses/

transform, and build upon the material for any purpose, even commercially." All that is required is that the user of the open resource gives appropriate credit, provide a link to the license, and indicate whether any changes have been made (Creative Commons, 2019). In theory, educational materials using other, similarly architected open licenses can be considered OER, but the overwhelming majority of openly licensed material in the world uses the Creative Commons licenses (Wiley et al., 2013).

2.5. Existing literature on OER and open textbooks

The last decade has seen significant growth in the availability and organization of open educational resources and, in turn, a growing volume of research on OER. Broadly speaking, research on OER can be grouped into the following categories:

- benefits of OER
- faculty and student perceptions (e.g., quality)
- benefits (e.g., cost-savings, increased retention)
- impact and student outcomes
- challenges and barriers to adoption (e.g., awareness, discoverability, time-constraints, attitudes)
- innovative models of OER production and/or distribution
- funding models and sustainability issues
- open practices and usage (e.g., remix practices, localization etc.)
- nature of 'open'

A complete survey of OER research is beyond the scope of this dissertation. This review draws upon literature on the implementation of open educational resources (OER) in higher education, with a geographic focus on the US and Canada.

The literature review is organized into the following sections:

- The promise of OER
- OER adoption barriers and challenges
- OER practices and usage
- Emerging research on open textbooks

2.5.1 The promise of OER

> The worldwide OER movement is rooted in the human right to access high-quality education. The Open Education Movement is not just about cost savings and easy access to openly licensed content; it's about participation and co-creation. Open Educational Resources (OER) offer opportunities for systemic change in teaching and learning content through engaging educators in new participatory processes and effective technologies for engaging with learning. – OER Commons

The current literature on OER seems to focus heavily on *the potential of OER to* scale up the provision of education and improve quality. It has been proposed that OER have the potential to reduce educational costs (e.g., Hilton III et al., 2014; Ikahihifo et al., 2017; Wiley, Green & Soares, 2012; William and Flora Hewlett Foundation, n.d), improve educational systems (e.g., Glennie et al., 2012; Olcott, 2012), personalize education (e.g., Ossiannilsson & Creelman, 2012; Silveira, 2016; Weller et al., 2015), promote social inclusion (e.g., Conole, 2012; L:ambert, 2018; Richter & McPherson, 2012), widen access to education (e.g., Cannell & Macintyre, 2015; Geith & Vignare, 2008; Lane, 2012; Okamoto, 2013) and support learner transition (e.g., Brunton et al., 2016; Kumar, 2009; Nikoi & Armellini, 2010). Broadly speaking, the literature identifies both pedagogical and institutional benefits to the adoption of OER.

At the institutional level, the potential of OER to increase access to educational opportunities by significantly lowering the costs of educational materials is considered to be a substantial motivator for participation in the OER movement, and the open textbook in particular. A number of studies have identified both altruistic and strategic motives that drive colleges and universities to adopt OER (e.g., Butcher & Hoosen, 2012; Pena, 2009; Phelan, 2012; Yuan et al., 2008; Yuan & Powell, 2013). Strategic reasons for adoption identified in these studies include the desire of higher education institutions to enhance their educational reputation, to attract talented students and staff, to drive innovation and to find better ways to accommodate lifelong and nontraditional learners. Access to philanthropic and governmental grants that support these types of activities and potentially support partnerships with other education organizations can also be a motivator. Altruistic reasons include a belief in open access—in the idea that information should be freely available to all, a commitment to social justice and a desire to improve access to educational opportunities for previously disadvantaged students.

At a pedagogical level, it is often argued that open textbooks can improve content quality through collaboration among a broad community of educators-specialists in a given area (e.g., Bell, 2012; Farrow, 2012; Okada et al., 2012; Pirkkalainen et al., 2014; Tapscott & Williams, 2008; Tosato & Bodi, 2012). This argument is aligned with one of the main ideas behind the open-source movement, which suggests that working together to share knowledge, resources, and best practices will propel everyone forward (e.g., Benkler, 2005; Lessig, 1999; Willinsky, 2005; 2006). Another potential benefit identified by the literature on OER, is the ability to easily update these resources to include relevant new information, perhaps improving pedagogy

(Commonwealth of Learning, 2006; Jena, 2009; Lipford & Chu, n.d.). Moreover, it is suggested that the customizable nature of dynamic material such as OER can spur pedagogical innovation – for instance, a textbook can be remixed with another material to produce a new learning pathway (Gordon, 2014; Matkin, 2009; Okada & Connolly, 2008; Thakrar et al., 2009). Butcher (2010) suggests that OER have the potential to enhance the capacity and competence of instructors to design and integrate instructional material into high quality learning programs, while Okada & Leslie (2012) argues that OER might have the potential to promote active learning by engaging students more interactively with a text, or even giving them the opportunity to contribute to the text's development.

Yet, despite the apparent opportunity presented by OER, only a small proportion of these resources are being used and reused by instructors in the manner envisioned by proponents and funders (Jansson, 2011; Ochoa & Duval, 2009; Petrides et al., 2010; Petrides et al., 2008).

2.5.2. OER adoption barriers and challenges

Several studies have looked at barriers to adoption, which are both systemic and individual. Two consecutive Babson OER survey reports found that most (>70%) faculty in higher education in the US remain unaware of OER, and adoption of these resources has yet to enter the mainstream of higher education (Allen & Seaman, 2014; 2016). Lack of awareness of open licensing also remains an issue, with several studies reporting that only a small minority of educators create resources and publish them under a CC license (e.g., Anderson & Leachman, 2019; Allen & Seaman, 2014; Kurelovic, 2013; Weller et al., 2017). For example, the OER Evidence Report 2013–2014 (de los Arcos et al., 2014), found that only about 13% of educators create and publish resources with a Creative Commons license, while general knowledge of well-established OER repositories appears to be low.

Kortemeyer (2013) cited four main issues that prevented widespread use of OER: time needed to discover and link suitable OER material into a suitable curriculum; lack of quality control and feedback procedures to improve content and reduce error; lack of faculty expertise in integrating OER into existing course management systems, and lack of faculty buy-in to the OER ideology. The 2014 and 2016 Babson surveys (Allen & Seaman, 2014; 2016) support the idea that the most significant barrier to OER adoption is the perception that too much faculty time is required to locate, evaluate, and incorporate material. In a study of eight US community colleges that participated in an initiative supporting faculty adoption of ready-made OER, many faculty reported that using OER requires more preparation time than when using traditional materials (Hilton et al., 2013). Some scholars have also noted the lack of ancillary materials such as test banks, homework assignment managers, and study guides that are often available from commercial textbook publishers being of concern to faculty (Cote, 2017; Lawrence & Lesterm 2018; Wang & Wang, 2017). At the same time, commercial publishers maintain sophisticated marketing channels and provide often-elegant instructional aids, adaptive learning, and assessment systems inextricably linked to educational content. These make it easier for faculty to opt for the *status quo* (Senack & Donoghue, 2016).

At the institutional level, Murphy (2013, p. 203) suggests a possible "lack of compatibility between the philosophy of OER and existing institutional cultures and priorities", and Weller & Anderson (2013) observe that a lack of business models may inhibit OER uptake (see also: Butcher & Hoosen, 2120; De Langen, 2011). A 2014 study by BC Campus (Jhangiani et al, 2016) noted that faculty in teaching-intensive universities in Canada cited university or department policies, including those that mandate the standardization of course materials, as barriers to adoption. In large introductory courses, for instance, in order to facilitate student mobility, academic departments often require that faculty adopt the same textbook across all sections. Since the choice of textbook is not an individual one, open textbooks have a harder time entering the classroom.

The BC Campus study also noted that lack of mechanisms for rewarding academics for their involvement in OER creation and dissemination can hinder adoption by faculty, particularly at research-intensive institutions, where overstretched faculty have little interest participating in activities that will not count toward tenure or promotion in rank, and are oftentimes not even credited toward time in service. As Weller (2014) notes, there is a long-standing cultural ecosystem surrounding the current use of textbooks in higher education that has yet to be adequately disrupted by the OER movement.

One of the primary challenges faced by the OER movement is that of long-term sustainability (Annand, 2015; Atkins et al., 2007; Dholakia et al., 2006; Kanwar et al., 2010; Koohang & Harman, 2007). In other words, simply creating OERs that are of good quality, openly licensed and freely available is not going be sufficient to ensure mainstreaming. Several studies have noted that institutional buy-in and commitment (i.e., via institutional policies, provision of institutional resources etc.) are key for achieving sustainable use and development of OERs (Bryant et al., 2014; Carey & Hanley, 2008; Tovar & Piedra, 2014; Yuan et. al, 2008). Olcott (2012), for instance, emphasizes the importance of institutionalizing the management of OER and OEP within current teaching and learning infrastructures to maximize the benefits of OERs at an institutional level.

2.5.3. OER practices and usage

Several studies have focused on ways to support academics to engage with OER, suggesting various OEP frameworks that can be used to OEP to enhance higher education curriculum design and delivery through the reuse of OER (Armellini & Nie, 2013, Wild, 2012; Hannon et al, 2013). These studies generally suggest that faculty are by and large willing to engage with open practices through the use and reuse of OER to enhance the design and delivery of curricula.

Other studies have focused on the benefits of open educational practices. A study on the role of OER in transforming pedagogy, for instance revealed how exposure to OER supports collaborative practices among educators (Petrides et. al, 2010). Weller et. all (2015) suggest that OER use encourages reflection by educators on their own practice, yet the authors do not provide detail on the nature of usage and whether there are differences in people who create, adapt or remix OER, versus those that 'simply' adopt.

Overall, however, researchers lack in-depth understandings of open practices performed by individuals in particular contexts, especially in contexts that don't advocate for openness and/or lack OER policies. Cronin (2017) attempts to fill this gap by exploring meaning-making and decision-making processes by university educators at an Irish university regarding whether, why and how they use open educational practices for teaching. The study challenges the assumption that it is the use of OER that leads to OEP, with Cronin noting that the opposite can be true as well. The author also points out that adoption of open practices and/or use of OER, does not necessarily imply commitment to the ethos of 'open:'

> While this may be the underlying motivation for many open educators, it is not a valid assumption for all open educators. Adjunct academic staff, for example, operate with a different set of structural constraints. For some, lack of access to institutional tools may

> act as a driver to adopt open practices; others may choose to avoid the risks of open practice due to the precarious nature of their positions.

Furthermore, limited research has been conducted to investigate the detail of OER reuse, remix and redistribution by different user groups. In fact, these practices are some of the most under-researched and poorly understood aspects of OER and OEP, which tend to focus on pedagogical practice at the expense often of other knowledge practices (e.g., design, production, distribution and reuse). In a study of the CNX repository, Ochoa (2010) indicates that “a third of the material (34 percent) is never reused inside a course and 44 percent is only used once. The 22 percent remaining is reused between 2 and 8 times” (p. 18). In his doctoral dissertation, Porter (2013) mentions that in his interviews with faculty they often brought up difficulties associated with repurposing and remixing resources developed by others. Overall, instructors noted that “for now, reusing OER in new contexts is a labor intensive process, requiring media skills as well as technical skills to extract usable media from existing formats for editing and redeployment” (p.138). In fact, some instructors suggested that it might be more efficient to create their own resources from scratch instead of trying to repurpose someone else’s design and content. Clearly, as Porter notes, creating new OER constantly from scratch “would be counter to the implied OER value proposition” (ibid.). However, he also notes that there is a lack of tools that make remixing easy or accessible for most people.

What appears to be missing from the literature on adaptation and reuse, is research that investigates what kinds of adaptations are made and whether or not those adaptations are, by and large, improvements over adopting OER as is.

2.5.4. Research on open textbooks

Research on open textbooks has focused largely on cost-savings (Allen, 2010, Bliss et al., 2013; Clinton, 2018; Hilton et al., 2014; Hilton & Wiley, 2011, Senack, 2014; Wiley et al., 2014) perceptions by students and faculty (Allen & Seaman, 2014; Bliss et al., 2013a; Bliss et al., 2013b; Hilton, 2016); learning outcomes and attrition (Fischer et al., 2015; Hilton and Laman, 2012; Robinson, 2015); barriers to adoption (Belikov & Bodily, 2016; Mishra, 2017); and, to a lesser extent, usage (Hilton & Laman, 2012; Hilton et al, 2013). Research focusing on 'cost-savings' includes studies of how much students typically spend on textbooks, how much they save in particular courses by using open textbooks, and how the cost of textbooks affects students' academic choices (Hendricks et al., 2017). Wiley and Green (2012) noted that the amount of money college students pay for traditional textbooks is ''26 percent of the cost of tuition at a public, four-year university'' (p. 83). Furthermore, in some community college contexts textbooks are more expensive than the tuition (Petrides et al., 2011). A 2014 NACS report found that first-generation students spend a lot more than others on their textbooks (Hill, 2016). In fact, they not only spend 17 percent more for their required course materials, they also acquire 6 percent fewer textbooks than other students. Overall, it appears that students are paying at least $480 per year on textbooks, with students in fields like Statistics and Economics often paying closer to $1000 (Association of American Publishers, 2016). Unsparingly, cost savings is often cited as the most important motivation for adopting open textbooks (Boston Consultancy Group, 2013; Cote, 2017; Belikov & Bodily, 2016; Ozdemir & Hendricks, 2017).

A number of studies that focus on 'cost' also compare e-texts to open textbooks, finding that these 'low-cost alternatives' are often not as affordable as they are made out to be. For instance, Hilton III & Wiley (2010) note that digital textbooks are usually impossible to resell, as they usually ‘expire’ after a certain length of time - usually between 6-24 months. Thus, even though a digital textbook typically costs around half that of the print version, the saving is less impressive when one considers the resale value of a new print copy, or the fact that students can often get a used copy for the same price or less (Butler, 2009). In terms of cost savings, some research demonstrates considerable cost savings for students and institutions in the adoption of open textbooks (Dimeo, 2017; Gallion, 2018; Hilton et al., 2014).

Research on ‘perceptions and attitudes’ explores how students and faculty perceive open textbooks, particularly in terms of the quality of these resources. The literature shows that the vast majority of students report open textbooks to be of the same or better quality than commercial textbooks. Bliss et al. (2013a) explored the perceptions of open textbooks from community college students and faculty members, reporting that 94 percent of 490 students said they found open textbooks to be of equal or higher quality than traditional textbooks. Lindshield and Adhikari (2013) found similar results in their study, which asked students at a large Midwestern, public institution of higher education to rate their experience with an open textbook, which they referred to as a ‘flexbook.’ Both online and campus students preferred the flexbook to a traditional text and rated the quality of the flexbook as high (Lindshield & Adhikari, 2013). Illowsky et al. (2016) reported on two surveys of students using an open textbook at a U.S. community college. The surveys were conducted in 2013 and 2015. In the 2013 survey, 87 percent of students rated the quality of the open textbook to be the same or better when compared to traditional textbooks, and in the 2015 survey, 93 percent of student respondents did so. Jhangiani et al. (2016) explored faculty perception of OER at post-secondary institutions in British Columbia, finding that more than half of respondents rated OER as good as or better than proprietary materials. Interestingly, but not surprisingly, those who had adopted OER rated it significantly higher than those who had not (Jhangiani et al., 2016).

Research on 'learning outcomes' considers how the use of open textbooks impacts on student grades, grasp of the curriculum and overall retention. While the number of studies looking exclusively at open textbooks remains small, preliminary research has found open textbooks to be at least as effective as traditional materials when measured by student performance and by soliciting student feedback (Clinton, 2018; Fischer et al., 2015; Robinson et al., 2014). For instance, in a large-scale study of students from six colleges and four community colleges in the US, Fischer et al. (2015) found that students using open textbooks and other OER did just as well or better than students using traditional textbooks in terms of grades and completion rates.

Research has also pointed to improvements in quality, flexibility, and professional collaboration as well as the increased potential for active learning and use of technology to improve the learning experience (e.g., Chadwell & Fischer, 2016; Ozdemir & Hendricks, 2017; Seid-Karbasi et al., 2017; Schreurs, 2014), although clearly more work needs to be done on the pedagogical impact of these objects. There are also very few studies that discuss how instructors and students use open textbooks, for example whether and to what extent faculty take advantage of open licenses to adapt and remix them, or how students interact with them and how they may interact differently with different formats (and for different purposes). In a survey of 127 instructors Pitt (2015) reported that 25 percent said using an open textbook had "enabled innovation or changed their pedagogical approach" (p. 146), but only a few explained in open-ended questions that they had adapted an open textbook. Furthermore, the study doesn't discuss how faculty are adapting and/or remixing open textbooks, what challenges they face doing so and what impact these practices may have on their teaching and students' learning.

In terms of methods and methodologies used, existing research relies heavily on survey instruments which, due to their very nature, sacrifice focus for scale and generalizability. Surveys also can't capture what they didn't set out to measure in the first place. What the research is missing, are more comprehensive descriptions and analyses of the sociotechnical processes and structures that are shaping open textbooks, as well as the ways that people and interact with these technologies in practice.

2.6. Methods and Methodology

In the following sections I discuss my methods and methodology in detail, justify their selection, and explain how they help answer my research questions.

2.6.1 Grounded theory

Research activities were conducted within the frame of grounded theory (Glaser & Strauss, 2007; Charmaz, 2006), which is a methodology that has been widely used in the social sciences to generate theory where little is already known, or to provide a fresh slant on existing knowledge. Moreover, grounded theory has been used in similar studies on technology implementation and organizational change in the past (e.g., Özbek, 2014; Shoham & Perry, 2009; Webster, 2016).

Underpinned by interpretivist epistemology, grounded theory is a systematic, inductive, and comparative approach for conducting inquiry (Charmaz, 2006). Key aspects include the constant comparative method (comparing data with data, data with codes, codes with codes,

codes with categories, etc.) and the generation and emergence of theory from what is observable in the data (Charmaz, 2006; Glaser & Strauss, 2007; Mavetera & Kroeze, 2009). In constructivist grounded theory, as pioneered by Charmaz (2006), reality is recognized as multiple and interpretive rather than singular and self-evident. Thus, "generalizations are partial, conditional and situated in time and space" (Charmaz, 2006, p. 141). Storytelling is key: the focus is on participants' interpretations of their experiences. Overall, however, the goal of all grounded theory is to enable the researcher to discover categories and relationships among them, articulate connections between components and processes and develop a substantial, context-specific theory that is grounded in the data (Strauss and Corbin, 1998). In my study I used the constructivist grounded theory approach for sampling, observations, interviewing, and analysis.

2.6.2. Multi-sited ethnography

My object of study wasn't a particular institution, program or company, but open textbooks themselves and, specifically, the sociotechnical system (composed of peoples, technologies and ideas) within which they are embedded and within which they circulate. Since that system does not have a single geographic site where it can be studied, the dissertation was necessarily multi-sited (Marcus, 1995) i.e., it was conducted among various people, institutions, projects, conferences and workshops. Multi-sited ethnographic designs have been employed in media studies (Hine, 2011; Howard, 2002; Radway, 1988), science and technology studies (Hine, 2007; Latour & Woolgar, 1979; Schlecker & Hirsch, 2001) and anthropology (Abu-Lughod, 2010; Krauss, 2016; Marcus 1995; 1999), among other, to "examine the circulation of cultural meanings, objects, and identities in diffuse time-space" (Marcus, 1995, p.96), particularly “objects of study that cannot be accounted for ethnographically by remaining focused on a single site of intensive investigation” (ibid.). In educational research, multi-sited ethnographies are yet to be widely used, although, Pierides (2010) argues that “in a contemporary world that is no longer necessarily organized by nearness and unity”, it is “now necessary” (p.57) to do so. Wolff (2015) also notes that educational ethnography is increasingly become more “multifaceted” in that researchers are becoming less concerned with “self-contained cultural or institutional islands” (p.58), and more with “complex networks of social situations” (p.58) and processes that play out at the same time in different localities, and that are spread over multiple social, material and technical contexts.

Multi-sited ethnography thus does not set out from a particular site, but rather from the construction of particular social practices and phenomena within a relational network that connects several sites (e.g., institutions, people, objects, projects and discourses). This requires a willingness to leave behind the traditional, bounded field-site and follow the object of study as it moves from place to place, and between different media. Accordingly, Marcus (1995) proposes a number of research strategies consisting of various forms of ‘following:’ follow the people, follow the things, follow the metaphors, follow the story, follow the biography and/or follow the conflict. In this dissertation, I follow the key stakeholders/ ‘relevant social groups’ (*follow the people*), I follow the open textbooks themselves (*follow the things*) and I follow how people think about open textbooks at various locations, positions and institutional contexts – in the mass media, in community colleges, in universities, among instructors/ users and among advocates to name but a few (*follow the metaphor*).

What makes multi-sited ethnography attractive is the prospect of systematically linking observations from seemingly distant geographical, institutional, organizational, cultural, technological and cognitive settings. The promise of multi-sited ethnography then, is, far beyond the simple multiplication of field-sites, a new way of describing systemic relationships and the interdependency of the many 'parts and subparts' of the sociotechnical infrastructure in which a technology, such as open textbooks, is embedded. A concern with multi-sitedness, on the other hand, is that by spreading the ethnographer too thinly across space, it jeopardizes anthropology's commitment to depth and thick description (Wolff, 2015). If, especially, the overall duration of the fieldwork remains the same as in single-sited research, it will only be possible to visit and investigate each site comparatively briefly, and build relatively superficial relationships with key informants. Thus, one of the key strengths of ethnography is in danger of being lost.

While this is an important corrective, I believe that, in the context of this study, the benefits of multi-sitedness outweigh the potential disadvantages. Since I follow the movement of content and ideas through the open textbook ecosystem, a systemic, multi-locale, multi-entity and multi-platform approach is fitting.

2.6.3. Research sites

A significant amount of fieldwork was conducted in the Greater Los Angeles area, where I am based, and where a number of community colleges and state universities are in the process of implementing open textbooks and OER/ ZTC degrees. Additional data was collected in Texas, where the open textbook publisher OpenStax is based. Data was collected over the period of 2 years, and included interviews with key stakeholders (both formal and informal) to understand how these objects are conceptualized, practiced and imagined; classroom observations to understand how open textbooks are used in practice and in conjunction with other learning materials, both digital and print; observations at several OER summits, training workshops and OER conferences around California in order to gain better insight into the on-the-ground challenges of open textbook implementation and into market trends; and a system analysis which provided a richer understanding of the various ways in which ‘open textbooks’ exist as digital objects. Prior to starting any research involving human subjects IRB documentation was submitted and good faith efforts were taken to respect their autonomy, well-being, and ensure equity.

A range of education institutions and organizations are represented through my fieldwork, with community colleges forming the largest cohort (n=13), followed by state universities (n=8), non-profit organizations (n=2), private colleges, research universities (n= 3) and for-profit companies (n=2).[10]

2.6.4. Interviews

2.6.4.1 Sampling

Grounded theory does not involve random sampling for research participants, as it is not concerned with statistical representation (Strauss & Corbin, 1998). Rather, it targets groups or individuals “who represent the important characteristics that researchers consider of interest to the study” (Williamson, 2006, p.87). During interviews and analysis, informants were selected using theoretical sampling, which is a core process of grounded theory. This method of sampling relies on the developing concepts in data collection and analysis to guide where, how, and from whom further data should be collected to develop a theory (Charmaz, 2006, 2014; Corbin &

[10] See Appendix I for full list of institutions

Strauss, 2014; Glaser & Strauss, 2007). Importantly, the total number of participants is not predetermined; it is determined by theoretical saturation of the emerging theory. In addition, I employed snowball sampling, which is a method widely used in SCOT, and which involves the researcher asking his initial informants to nominate others, who are seen relevant to the technology (Bijker, 1995). Through a series of nominations the researcher uncovers a larger sample until no relevant new actors are mentioned.

2.6.4.2 Relevant social groups

Based on the above two sampling methods, the following groups and informants were selected for this research project:

1. **Instructors as authors:** This category includes instructors who have written open textbooks and who may or may not currently be using them in their own courses. They provided me with information about the design, authorship and publishing process and how digital labor is configured around these processes. Eight (n=8) informants were interviewed in this category, representing both the sciences and humanities.
2. **Instructors as users:** This category includes instructors who have adopted open textbooks in their classes but who haven't authored the texts themselves. They provided information about adoption challenges, the day to day use of open textbooks and the extent to which they have remixed, modified or supplemented these resources. They also provided insight into the ways in which the open textbook has or hasn't changed their instructional design and teaching practices. This category also includes instructors who have taken on leadership roles on their

campuses to promote OER adoption. In total, twelve (n=12) informants were interviewed in this category, representing both the sciences and humanities.

3. **Students:** This category includes students who are enrolled in one or more courses using open textbooks. They provided information about how open textbooks are accessed and used in practice, as well as insight to potential accessibility issues and/or barriers. Students were interviewed informally in the classroom. In addition, six (n=6) students were selected for more in-depth interviews.
4. **Open publishers:** Editors, project managers, designers and engineers at open textbook publishing companies and organization provided information about the publishing process and what it entails, as well as the economic and peer-review model of their company. Directors and CEOs were also interviewed where possible to provide insight into the strategic vision of the organization and their views on the future of open education more broadly. Ten (n=10) informants were interviewed in this category.
5. **University staff:** Librarians and other university staff (e.g. repository managers and OER coordinators) provided me with information about current barriers to open textbook adoption on their campuses. Interview questions also addressed issues such as faculty awareness of open textbooks, open textbook 'discoverability,' the role of the library in open education initiatives, quality-control issues, intellectual property and copyright issues, and institutional support promoting OER adoption (e.g. faculty grants). Eleven (n=11) individuals were interviewed in this category.
6. **Policy makers and high-level administrators:** They provided information about the policy and institutional trends shaping the implementation of open textbooks, including the technical, economic and infrastructural factors that have, so far, inhibited their widespread

adoption. Questions addressed issues of funding, sustainability, policy/ institutional priorities, legislative developments, the role of the state in textbook provision and other. Three (n=3) individuals were interviewed in this category.

In total, fifty (n=50) formal interviews were performed. Several informal interviews also took place at various sites during fieldwork. Using a semi-structured interview protocol I interviewed participants between January 2017 and February 2019. Where a face-to-face meeting was not possible, the interview was conducted via video-conferencing software, or over the phone. Each interview lasted approximately 60 minutes and was audio-recorded and transcribed verbatim.

2.6.5. Observations

While in grounded theory, interviews are typically the primary method of data collection, observation offers a distinctive insight, revealing what people are really doing, as opposed to what they say they are doing. (Laitinen et. al, 2014). There were two main sites for observation: (1) classrooms, where open textbooks are being used as part of the curriculum, and (2) OER summits, training workshops and conferences, where open textbooks were promoted, discussed and theorized/analyzed.

2.6.5.1. Classroom observations

Observations took place in three classrooms at two California State University (CSU) campuses in the Los Angeles area over Spring 2017. The purpose of the classroom observations was to observe how students and instructors are using textbooks in practice, since there is often a disjuncture between how people say they use electronic software products and devices, and how they actually use them. I initially wanted to perform classroom observations both at the CSU and at an LA community college, but due to logistical challenges I ended up performing observations only at the CSU. Nevertheless, the two CSU campuses I selected were radically different in terms of geographic location in the city (and thus access to resources), available facilities and student body composition. As a result (or perhaps therefore), there were also clear differences in institutional culture.

This choice was intentional, as I wanted to see whether and how context impacts on how open textbooks are conceptualized, realized and used. The courses I observed were in the Department of Mathematics (2 courses) and the Department of Art (1 course). Specifically, I observed a course in introductory Art History (specifically: World Arts*:* Africa, Oceania and the Americas), a lower division Linear Algebra course and an upper level Number Theory course. The choice of disciplines was also intentional, as I wanted to investigate whether there are differences in how open textbooks are used in the arts/humanities classroom versus in STEM fields, such as mathematics. In total, I estimate spending fifty hours in the three classrooms over the period of four months.

In all classrooms, I carried out non-participant observations, where I did not take part in the activities observed. The class was informed of my role as an observer-researcher by the instructor, making it an overt observation. I observed each class for a total of at least ten hours, carrying out semi-structured observations (Gillham, 2008), guided by specific observation themes of interest. I started each session with descriptive observation (Robson, p.200) where I observed the situation non-judgmentally to create a basic narrative account on the space, setting, actors, activity and time of events. Then I focused the observation on several key themes. The key observation themes were developed around the themes of pedagogy, devices, materiality and hybridity as it relates to the ways in which the digital and print intersect.

2.6.5.2. Summits, workshops and conferences

Between November 2016 and November 2018, I performed observations and informal interviews at a number of open and digital education conferences, open textbook summits, working group meetings and training workshops in California. The conferences included OpenEd, the World Conference on Online Learning, SXSWEdu, and the Open Educational Global Conference, and took place in the US, Canada and Europe. At these conferences, I attended presentations, paying particular attention to the question-and-answer sessions, where educators often discussed best practices in terms of teaching with open textbooks, along with the challenges they encountered in implementing them. I also built contacts with potential informants, had informal conversation with educators, publishers, librarians and technologists, collected marketing material and got a feel for where the open textbook industry is headed.

In addition to these international events, I attended two consecutive OLC Collaborate events in California, which were jointly organized by the California State University and the Online Learning Consortium. These events were geared toward administrators in California higher-ed and focused explicitly on open textbook implementation. The first OLC event, titled "Textbook Affordability + Your Campus: Strategy, Data, and Sustainability," took place in San Francisco in February 2017. The second, titled "Expanding Textbook Affordability Programs on your Campus and Requesting Additional State Funding Opportunities", took place in Los Angeles in January 2018. The purpose of attending these events was to hear the concerns of administrators in terms of implementing open textbooks, and understand how they make sense of these objects, i.e. how they view their potential.

Furthermore, I attended a number of summits and training workshops in the Los Angeles area, which were geared toward practitioners (i.e., instructors and librarians) in the community college arena, who are developing and using open textbooks. These included one OER Summit and one ZTC Degree Summit at College of the Canyons, an OER Regional Meeting at Rio Hondo College organized by the OER Task Force of the Academic Senate for California Community Colleges. Finally, I attended several video conferencing calls organized by the Community College Consortium for Open Educational Resources meant to provide support and training opportunities to instructors, librarians and other staff at community colleges across the country working on implementing OER.

2.6.6. Field notes

For note-taking, I used my laptop and a paper notebook. Word processing software was used for the classroom observations, which allowed me to incorporate screenshots from the textbooks used, as well as notes related to pedagogy, content and more reflective comments. Using a word processor also provided the editing capacity for particular ideas to be developed later. The ability to color text in the word processing software thus allowed me to separate comments into distinct categories representing different analytical themes and emerging codes. The software used necessarily constrained the ways that data could be saved and arranged. The linearity of word processing documents was one crucial influence, encouraging sequential note taking and limiting the possibilities for connection between entries. I acknowledge that my field notes developed according to the material constraints of the word processing software I was using, as well as the social conventions of note-taking.

In addition to the word processing software, field notes were also taken in a paper notebook. This note-taking method was primarily used during conference/ workshop observations, interviews and when engaging with reading material or literature related to this research. The paper based notes allowed me to record quick insights and ideas without having to access the word processing documents stored on the computer. However, in my analysis I did not treat these notes as separate ‘offline’ contributions opposed to the ‘digital’ word processed documents, but as part of a multifaceted field note method. I read through my field notes many times, searching for emerging themes, and writing memos when an interesting idea occurred to me. Eventually, I coded my notes and memos along with my interview transcripts (see section 2.6.8. for details).

2.6.7. System analysis

A common limitation of OER research is to think about openness in terms of separate tools and processes rather than an integrated and dynamic system (with multiple sub-systems). In short, a system is a complete whole composed of parts that are necessarily related to each other in accordance with rules. In a system analysis we look at the various parts that make up a system and how these parts interact and work with each other (i.e., their interconnectedness) for the purpose of understanding the whole. This opens up opportunities for identifying inefficiencies, problems and areas of friction, as well as opportunities for improvement. In terms of organizations, systems are typically composed of people, processes/ procedures, technologies (e.g., computing and communications hardware, operating system and application software) and data/information. These components interact with one another for some specific purpose. In the case of open textbooks, a system could be seen as composed of various components that interact in order to facilitate the transformation of data to information, thus enabling (or not) content use and reuse.

Systems cannot be understood in isolation from the other systems and processes that they intersect with. This is particularly true in computing, where systems (and sub-systems) are increasingly being interconnected to become part of a complex whole. For example, the open textbook publisher OpenStax, which is used as my case study in Chapter 5, collaborates with a number of for-profit technology and publishing companies that 'absorb' OpenStax content and make it available through their own technology platforms, with value-added solutions wrapped around it (e.g., online homework systems; flashcards, tests etc.). Challenges along these lines, include the need for interoperability and structuration of data. Interoperability refers to the ability to transfer data across separate heterogeneous systems and databases, both within and across organizational boundaries. Structuration of data (e.g., use of specific formats and standards for organizing educational content) serves as a tool for supporting interoperability and exchange of data. If the information found in textbooks and other OER, however, is not properly structured or coded to ensure consistent transfer and interpretation by different software, reuse can be significantly hampered.

Thus, given that open textbooks are today increasingly dependent on highly distributed computational resources, that these resources are themselves dependent on modular relationships that ensure their interoperability across market players and technical boundaries, and that the promise of open textbooks lays in part in their ability to foster greater reuse and remixing of knowledge components, it is important to be able to analyze open textbooks in those terms, that is as computing objects that are distributed and interoperable within horizontal markets. Such kinds of analysis have been performed in the framework of 'platforms studies,' works that have sought to restore the foundational role of hardware in the analysis of creative practices—e.g., software development, gaming, image editing and synthesis— taking place on computing platforms such as the Wii, the Commodore, or the Amiga (Montfort and Bogost, 2009; Jones and Thiruvathukal, 2012; Altice, 2015). The theoretical approach here is to go beyond mere code, and reach "deeper, to the metal," at the "base hardware and software systems that are the foundation of computational expression." (Montfort and Bogost, 2009) As such, works in the series have provided extraordinary detailed accounts of the intricate relationship between hardware, system code, and applications and the creative spaces this relationship makes possible or denies.

In this project, I perform a similar type of analysis by mapping out the various parts that make up OpenStax (software, data components, procedures, people that produce information etc.), the infrastructural resources they depend on, the interfaces that allow for interoperability with other systems (e.g., file formats for data exchange, and APIs), as well as market players and their various alliances. Such a map provides for greater insight into the nature and evolutionary paths of open textbooks given their technical and market structure.

2.6.8. Data analysis

In constructivist grounded theory, data and analysis are seen as social constructions reflecting both the participant and the researcher (Charmaz, 2014; Hallberg, 2006). In my data analysis, I was mostly guided by the "constant comparative method" outlined by Glaser and Strauss (1967, p.105) in their grounded theory approach, where data analysis is undertaken concurrently with data gathering. The advantages of this method are that the analysis “correspond[s] closely to the data” (ibid., p.113- 4), and the theory that emerges is derivative whereby “the data suggest the theory rather than vice versa” (Cohen et al, p.138). Robson‘s (1996, p.401) qualitative data analysis strategy also helped me create relevant categories, note patterns, cluster similar objects, discover possible relationships to link between variables and relate findings to general theoretical framework. Guided by the analytic methods for qualitative research (Miles and Huberman, 1994), after I transcribed the voice-recorded interviews, I affixed codes by hand to the data to distinguish its source from different respondents, from interviews, observations, systems analysis findings or from memo and reflection notes during and after data collection. Coded emerged as I sifted out the key themes and developed a scheme guided by interesting incidents/findings, themes from my research questions and conceptual framework. Results of early interviews enabled refinement of interview questions for subsequent interviews. New codes were added as they emerged and previous transcripts were checked for these codes. I continued this process until I could not identify any new codes, categories or themes; that is, the point of data saturation was reached. Across the data from different research instruments, I triangulated and confirmed patterns of emerging relationships or discrepancies.

2.6.9. Issues and problems

In terms of issues and problems I encountered during fieldwork, my classroom observations yielded less rich data than I had hoped for. This had largely to do with the fact that the textbooks remained largely absent from classroom practice, and I was rarely able to observe students and instructors interacting with them. As well, the art history course I observed was largely lecture-based with minimal references to the text, which made it hard to draw conclusions about how the materiality of the open textbook was or wasn't shaping pedagogical practice. This 'invisibility' of the textbooks, while very useful in terms of thinking about the use and impact of open textbooks, generated little actual data that was used in the subsequent analysis and writing of this dissertation. As a result, I decided not to include my observations from the art history course in my discussion here (findings from the math observations are discussed in Chapter 6).

In addition, my initial intention was to observe math students in study groups, as well as in the classroom. However, my plan for study group observations did not materialize. Despite several in-class announcements and class emails, none of the students responded to my calls for participation. Some of the students that I had built a friendly relationship with and who I approached in person said that they did not participate in study-group sessions because of work/ family commitments. Given that the two mathematics courses I observed took place on a campus serving predominantly to working-class and nontraditional students, it is possible that the majority of students in these classes did, due to time constraints and irregular schedules, indeed not study in groups.

As a result, I had to revise my original research questions focusing on materiality and pedagogy to reflect my lack of observational data. Nevertheless, these are questions I intend to pursue in subsequent projects.

2.7. Conclusion

This chapter was divided into two parts. The first part provided definitions for some key concepts and terms used throughout this dissertation. It also provided a survey of existing research on OER and open textbooks and identified some of its gaps and limitations. The second part provided a description of the methods and procedures used in conducting this study. A brief overview and rationale for grounded theory methodology was offered. Further, the location for the setting of the study was outlined. Approaches to sampling, data collection, and analysis specific for a grounded theory approach were detailed. A grounded perspective emphasizes knowledge generation that contributes to a meaningful explanation of how open textbooks are constructed and how they in turn construct knowledge and knowledge claims about teaching and learning. In the ensuing analysis chapters will demonstrate the insights generated through this method.

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CHAPTER 3: A LONG VIEW OF OPEN

3.1. Introduction

Much of the conversation around open textbooks has failed to adequately place them in an historical context. Overwhelmingly, open textbooks are presented in the media and in public discourse as a radically new phenomenon without historical antecedents. Even when connections to earlier incarnations of open education such as open universities, Learning Objects and MOOCs are drawn, they rarely go beyond a mere mention. This a-historicity in the language that surrounds open textbooks perpetuates the confusion that surrounds the term 'open' and its equation with something that is primarily (or, even, exclusively) free of cost. Perhaps more importantly, it leads to hyperbole and misplaced expectations about what open textbooks are capable (and, likely) of achieving in the higher education space. Detached from their past, open textbooks are presented as a new and disruptive force destined to fix the college affordability problem in the US. This technological 'solutionism'[11] (Morozov, 2013) assumes that new technological interventions (e.g., open textbooks) will somehow stimulate change by themselves – i.e., that adopting an open textbook will somehow automatically close gaps and improve outcomes.

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[11] Technological solutionism refers, broadly, to the idea that complex social problems can and should be fixed with technology. According to Morozov (2013), "the urge to replace human judgments with timeless truths produced by algorithms is the underlying driving force of solutionism." It is sometimes also referred to as 'tech solutionism' (e.g., Siegel, 2018), 'technosolutionism' (e.g., Lindtner et al., 2016) and 'technochauvisim' (Broussard, 2018). Watters (2013) uses the term 'ed-tech solutionism' to describe solutionist thinking in ed-tech: "I would contend too that […] ed-tech (as well as the journalism that's been cultivated to cover it) easily fits into Morozov's larger arguments about Silicon Valley: context-free, deeply ahistorical, and suffering from a poverty of theory but certainly not from a lack of ambition."

This type of thinking is prevalent not only in the media, but also within policy circles. Former US Education Secretary Arne Duncan, for example, said in 2011 (Student PIRGs, 2011):

> Open Educational Resources are critical in helping us meet the President's 2020 goal: to make America number one in the world for college graduates. These free resources can create high-quality educational opportunities for students, veterans and returning workers, grow our economy, and help us out-educate, out-innovate and outcompete the rest of the world.

Duncan's statement neatly encapsulates the limitations of the popular narrative around open textbooks, and OER more broadly. The first, is the reduction of 'open' to mean 'access' or 'free', which suggests a product or transaction and which is the result of a contracted and, as I demonstrated below, misplaced misunderstanding of what openness in education entails. The second, is impossible expectations of 'disruption' combined with a fundamental misunderstanding of how technology works, and what it can offer to the teaching and learning process. This chapter offers an alternative perspective on openness in education grounded in history and informed by ongoing debates around the meaning and potential of educational technology, as well as the role, value and future of higher education more broadly. This historical reconstruction offers a more nuanced understanding of openness, beyond the one imposed by the current developments in digital technologies. It also demonstrates that questions of meaning, purpose and opportunity in relation to 'openness' and open educational artifacts have always been driven by social, economic and cultural factors. It thus foregrounds the discussion in subsequent parts of the dissertation.

This chapter is structured as follows: I begin by charting the history of open education back to the Middle Ages so as to ground the current discussion and provide a basis for understanding how notions of openness in relation to learning have evolved over time. Looking at medieval student-led universities, 17th century coffee houses and industrial working men's clubs, I show that the idea of sharing educational materials is far from new, and that even before the advent of the Internet people were thirsty for access to knowledge. I thus argue against the common notion that digital technology – and particularly the web 2.0 – has been the primary driver of the open education movement. In addition, I show that the equation of 'open' with 'free' is a recent phenomenon

and that earlier instantiations of open education were more concerned with personal growth, civic participation, notions of border/boundary crossing and positive liberties, such as access to better job opportunities and lifelong learning.

I then turn my attention to how open education was transformed through rapid technological developments from the 1980s onward. I discuss how the rise of the free and open source software movements reframed how openness and its potential were understood and how, gradually, being 'open' came to be identified with the ability – or not – to use, create, edit, and share content under open licenses and through social media and digital tools. I argue that the commercial success of open education ventures such as the MIT OpenCourseware project and, later, MOOCs, both introduced 'openness' to a broader audience and reduced its meaning to yet another form of 'disruptive innovation' driven by digital technology. My intention in this section, as well, is to ground open textbooks within the broader open content movement of the 1990s and 2000s, which encompasses developments like Learning Objects and MOOCs, in order to discuss some of challenges and shortcomings of these earlier 'incarnations' of openness and underscore connections to current technical, pedagogical and economic issues that also mark the open textbook phenomenon.

In the last section, I examine contemporary discourses around open education, offering a critical commentary on the perception of openness as both a disruptive force in education, and a potential solution to contemporary challenges – i.e., rising tuition costs, low completion rates and lack of student engagement. I argue that popular framings of open textbooks in the media and in policy discussions are part of a longer historical lineage of 'disruption' and technical 'fixes' that will, presumably, create a new culture of mass learning (but which time and time again fail to do so). Thus, I argue, open textbooks must be viewed and understood within not only a broader history of openness, but also a broader history of technology in the classroom.

3.2. Open education in the 'pre-internet' era: a brief history

> Unfortunately, Open Education has so far shown a conspicuous disregard for historical precedents that might offer some valuable lessons on the subject of educational change. – (Mai, 1974, p. 2)

Today's discourses around 'openness' in education revolve around the rise of MOOCs and OER and the potential to increase educational opportunities for an ever-expanding global population. The growth of these movements in recent years has marked an increasing interest in defining and marking the boundaries of 'open,' particularly in relation to platforms and artifacts like the aforementioned. However, the idea of 'opening up' education has a long history, and is strongly linked to modern reform movements and ideas, such as 'open entry', 'open classroom, 'open curriculum', and, most importantly, 'open' to all people and target groups (Mulder, 2015; Oliver, 2015; Peters & Britez, 2008; Peters, Liu & Ondercin, 2013).

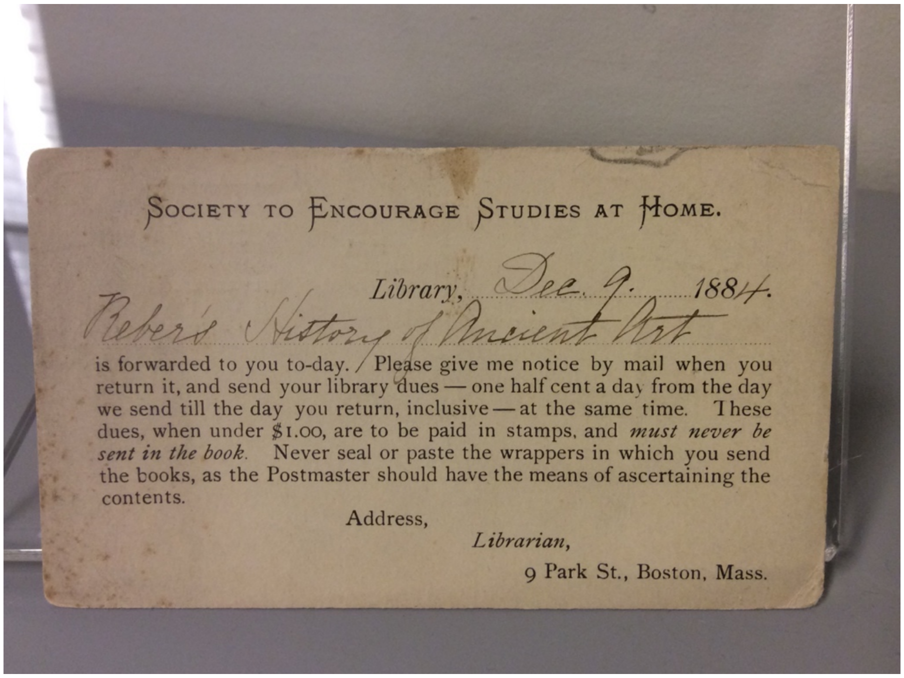
Couros (2004, 2006) and Wiley (2006) locate the root of openness in regard to education in the free software and open source movements of the mid-late 1980s, however Peters & Britez (2008) trace the idea back to the Enlightenment and its focus on citizenship, individual rights, social progress, and the democratization of knowledge. Peter and Deimann (2013) go even further back, situating the philosophical underpinnings of openness to the short-lived student “universities” of the late Middle Ages, where education was escaping the traditional borders of the monastery. Medieval student universities were mobile, international and governed by informal rules, and they were in large part attended by working class or poor people –usually men – who were often already professionals in various fields. Scholars from all over Europe were invited to deliver lectures at no cost and there was, to a large extent, an open curriculum, which gave students the opportunity to explore a wide range of interests and, even, develop new ones. While these universities have little in common with contemporary open universities, their practices do reflect values that are found in current discussions about openness, such as student-driven learning, self-actualization and access to knowledge for all (ibid.) However, student universities were short lived. Over time, higher education became increasingly formalized at institutions such as Oxford, Paris and Padua, and with that exclusionary to the general public (de Ridder-Symoens, 1991; Rashdall, 1895).

During the Industrial Revolution another form of open education began to take shape. As coffee gained popularity around the Middle East and, later, Europe, coffee houses started popping up all over, becoming a center of social activities, community news, and intellectual stimulation. Coffee provided the opportunity for people (generally men) to gather, read and participate in lively discussions covering politics, current events, philosophy, religion, business, science, literature and the latest gossip. Political, social and academic debates among patrons were expected, but social standing and status were not important. For the price of a penny for admission, anyone could sit at a table with another person and engage them in conversation - “[f]reedom of class, freedom of thought and freedom of debate” (McQueen, 2004, p. iii) were supported, encouraged and celebrated.

Figure 3.1. Interior of a London coffee house; c.1690-1700 (source: British Museum, London)

In addition, some coffee houses had libraries with as many as 2000 volumes (Ellis, 1956) and provided access to yet unpublished material, at times preceding actual publication by a few years (Levere et al., 2002). Coffee shops also attracted scholars interested in promoting their work, along with intellectually curious folks of all classes and backgrounds (Ellis, 1956) eager to join "the social meeting place in which the creation of modern society was discussed and developed" (McQueen, p. iii). Since coffee shops provided a public sphere in which free thinking and vigorous, democratic conversation were encouraged, an alternative learning "institution", supplementary to the university, was developed. Peter & Farrell (2013) suggest that coffee houses represented "an unprecedented moment of openness" (p. 175), because they provided a space in which education, once accessible only to a privileged few, was made accessible to any man at (almost) no cost. Much like the Medieval student university, however, the 17th century coffee house was short-lived. Slowly, but gradually, coffee houses began adopting increasingly restrictive rules that ultimately transformed them into private clubs and exclusive societies. Failing to preserve the openness that had made them successful in the first place, by the mid-1800s they had all but disappeared. (Peter & Farrell, 2013)

The 18th century also saw the establishment of self-education societies and independent educational associations. As new forms of work organization brought unprecedented numbers of people to the cities, and as the invention of the printing press saw a rapid increase in the production and circulation of information, popular desire for literacy increased (Peter & Farrell, 2013). Soon after, the development of the rail system in the United Kingdom, Germany and the US enabled the formation of a new postal system, which soon gave rise to correspondence education taught by mail (Tait, 2003). Correspondence education, which is widely regarded as the precursor to distance learning, is said to have begun in England in 1844 with Isaac Pitman's shorthand course, which saw Pitman correcting students' work and sending it back to them. In 1873, Boston-based Anna *Ticknor* founded the Society to Encourage Studies at Home, which was the first *correspondence school* in the United States, and which encouraged studies at home for women regardless of race, location, class, or financial disposition. Working with 200 teacher volunteers, almost all of which were women, Ticknor's society provided correspondence instruction to more than 10000 women over the course of 24 years (Brennan, 2016; Caruth & Caruth, 2013).



SOCIETY TO ENCOURAGE STUDIES AT HOME.

Library, Dec. 9. 1884.

Reber's History of Ancient Art

is forwarded to you to-day. Please give me notice by mail when you return it, and send your library dues — one half cent a day from the day we send till the day you return, inclusive — at the same time. These dues, when under $1.00, are to be paid in stamps, and *must never be sent in the book*. Never seal or paste the wrappers in which you send the books, as the Postmaster should have the means of ascertaining the contents.

Address,

Librarian,

9 Park St., Boston, Mass.

Figure 3.2. Resource request card to the Society to Encourage Studies at Home, 1884 (source: Michigan Tech Blogs)

From the late 19th century on, miners' institutes (also known as workingmens' institutes) emerged across the UK and in parts of the US to take care of the growing intellectual needs of the working class (Gil-Jaurena, 2013). These institutes were financed, controlled and managed by the communities in which they were situated and were the focus of social, educational and cultural activity in the mining town. For a small subscription fee they provided facilities such as reading rooms, smoking rooms, chess rooms, billiard rooms, meeting halls and libraries to their members. Nearly all institutes had libraries and many of them offered adult education classes to their patrons. Speaking of Great Britain's miners' institutes, Hywel (1976, p. 190) notes that "there was no comparable educational institution, generated entirely by a proletarian culture, existing anywhere else in the world during this period."

Co-operative societies of that era also participated in informal educational activities, advocating the idea of lifelong learning as a means to self-actualization. Education at the co-operatives was strongly influenced by the enlightenment idea that the simple distribution of knowledge could have transcendental effects. Books and lectures needed simply to be shared among the people like tea and flour - a typical co-operative metaphor - in order to transform society (Woodin, 2011). This demand for knowledge was met through the proliferation of co-operative libraries, journals and newspapers which were distributed both at the local and national levels and which became intertwined with a range of collective self-help initiatives (ibid.). One such co-operative, the Rochdale Pioneers, was so tenacious about its commitment to education that by 1875 it had a library of around 11,000 volumes, a full-time librarian and eleven reading rooms and laboratories. In fact, in the 1870s and 1880s there were more co-operative libraries than public libraries across Great Britain (Rose, 2002). Meanwhile, reading aloud in pubs and on street corners was also quite popular during the 18th and 19th centuries, contributing to the formation of a shared literary culture in which books were practically treated as public property and as ‘open’ to everyone (ibid.).

The 20th century continued to see educational movements and ideologies form that fought – in one way or another - to ‘open up’ K-12 schooling, post-secondary education and lifelong learning. At the K-12 level, educators like John Dewey (1907; 1916) and Maria Montessori (1912), sought to challenge the centrality of the instructor in the classroom by highlighting the freedom, autonomy, creativity and individuality of the learner. Their educational philosophy was motivated by the belief that learners want to – and should – exercise agency in their studies by, for instance, having personal choice in the focus of their classroom studies, conducting inquiries about potential topics of study, having hands-on educational experiences instead of a strictly textbook-focused education, taking responsibility for their educational decisions, and understanding how education and community are related.

While Montessori's (1912) discovery education model emphasized self-paced exploration and organic collaboration, Dewey's (1907; 1916) conception of openness in education was largely about connecting the activities of educational institutions to those of the surrounding society. He believed that schools should be made a form of active community life, rather than "a place set apart in which to learn lessons." (Dewey, 1916, p.27) By fostering the spirit of social cooperation and community life, as well as encouraging learners to become reflective and inquisitive agents in their own learning processes, Dewey believed that educational institutions would be better equipped to produce functional citizens for a democratic society. As Dalsgaard & Thestrup (2015) have suggested, an important point that can be drawn from Dewey's thoughts on the role of education in society, is that 'opening up' educational resources and making them available to everyone is not the same as interaction with and participation in society.

The concepts of individual freedom, self-directed inquiry, social cooperation, community ethics and harmony are also reflected in Karl Popper's (1945/2012) conceptualization of the 'open society' in the early 1940s. While Popper was not the first to write about 'openness' or even the idea of the open society (Tkacz, 2012), he was the first to clearly articulate the idea of 'open' as tolerance towards opposing ideas, religious thoughts and critical questioning (Mishra, 2017). For Popper, central to the notion of open society is the free flow of ideas, which implies an acceptance of vigorous but respectful disagreement and constructive criticism as necessary agencies for the improvement of society and its members (Lam, 2013). Given that an open society places great political and intellectual demands upon its members, "requiring the participation of a well-informed, socially aware, and critical citizenry in scrutinizing political debates, examining government proposals, and making sensible decisions" (Lam, p.845.), education has crucial importance and is inexorably linked to a society's social, economic and political well-being. Thus, for Popper, much like for Dewey, 'opening up' education was ultimately about repairing the disconnect between people and governments.

During the 1960s and 1970s, educational reform was at the center of a widespread public debate on cultural and social renewal. At the time, the traditional classroom was often conceptualized as an oppressive, rule bound, authoritarian teacher-centered and teacher-directed structure that demanded obedience, stifled creativity, and crushed the student's voice (Baker, 2017). This view was often contrasted with the vision of the 'open classroom' model[12], where the teacher functions as a facilitator and partner in the learning process, not as a dispenser of knowledge, and where students are encouraged to rethink self and society (Kohl, 1971; Silberman, 1973). Brazilian educational philosopher Paulo Freire (1970, 2000, 2018) explored the nature of education as an oppressive structure, proposing a new pedagogy that changes the relationship between the 'oppressor' (i.e., teachers, administrators) and the 'oppressed' (i.e., students) by promoting critical thinking, encouraging students to resist indoctrination and, ultimately, empowering them to reach emancipation. Freire believed that through an open and on-going dialogical process of problem posing or 'problematization', with students as subjects of their learning, a critical consciousness - or 'conscientization' – forms and, as such, students organically participate in altering their lives, both as individuals and collective beings (Darder, 2014).

[12] For a recent reflection on the legacy of open classrooms and open schools, see this NPR segment: https://www.npr.org/sections/ed/2017/03/27/520953343/open-schools-made-noise-in-the-70s-now-theyre-just-noisy

While the influences of Freire and Popper differ greatly, these ideas are similar to the requirements of citizens in Popper's open society. Clearly, the two thinkers shared an understanding about the importance of a 'critical approach' to education and its role in empowering individuals to take a critical stance toward information and to "exercise their reason in ways that lead to the construction of integral knowledge, which opens the door to further questioning and greater curiosity of why the world is as it is and how it might be different" (Darder, p.5). Freire's approach also shows the need for a change not only in curriculum and the educational materials used, but a complete overhaul of traditional pedagogy to meet the needs of a more open and more just society.

Many of Freire's ideas about the need to deconstruct the official standards of knowledge imposed by hegemonic schooling and to design learning environments which allow open dialogue, greater autonomy and creativity for learners, are also reflected in the works of Ivan Illich (1973), Paul Goodman (1971) and John Holt (1974; 2005; 2016), intellectual fathers of the 'deschooling' movement. Occasionally mentioned as a precursor to the open education movement (Antliff, 2012; Nyberg, 2010; Peters, 2008), deschooling represented a broader loss of faith in institutionalized learning and a desire to find (and create) meaningful educational alternatives outside the closed structures of schools through, for instance, individualized informal learning within the broader community. Particularly, Illich (1971) advocated the idea of using new technology as a means of creating networks - as opposed to institutions - that are temporary, autonomous, nonhierarchical, and that facilitate a variety of diverse modes of learning and community interaction (Hart, 2010). These "learning webs" described by Illich some 20 years before the invention of the World Wide Web, would be "readily available to the public and designed to spread equal opportunity for learning and teaching'' (Illich, p.77) Within them, the roles of learner and teacher would not be fixed and learning would be far more collaborative, distributed, and personalized than was the norm through traditional schooling (Saadatmand, 2017). Learning webs, he argued, should facilitate the following (Brown, 2008):

1. free and universal access to learning resources;
2. skill exchanges, where people could advertise their own availability and skills;
3. peer-matching, where they could locate peers and available skills;
4. and access to professional educators, rather than to educational programs or institutions.

Thus, through learning webs, Illich "postulates the potential of technology to decentralize educational systems to make learning resources available to all at any time, and to promote self-directed learning supported by social interactions" (Saadatmand, 2017, p.20). The deschooling movement also fueled an interest in the use of textbooks alternatives, such as radio, television, films and computers for educational purposes. While these media had been used for some time as 'supplementary' material, by the 1970s they were often integrated into the instructional system (Dewal, 1994).

In the 1960s and 1970s, a heightened interest in the provision of adult education, the growth of educational broadcasting, and the spread of egalitarianism in education also ushered the growth of open universities and distance education (Perry, 1976). Best known is probably the Open University (OU) in the UK, founded in 1969, at a time of significant developments in information technology and mass media. Access to higher education was extremely limited at the time, with only about 5 percent of the UK population being able to attend university, and while efforts were being made to expand provision, many people were still left behind unable to meet entry level qualifications or take time off work to study full-time (McAndrew, 2010). In an effort to provide education for people with no or limited access to the traditional educational system, the OU utilized existing technology to offer courses that addressed geographic barriers as well as the barrier of formal qualifications. It thus interpreted 'open' as "open as to people, places, methods and ideas" (McAndrew, 2010) and, contrary to common understandings of 'open as free', the university charged – and still charges – tuition fees (Smith & Seward, 2017).

But while the OU quickly became the most successful open distance teaching institution in the world – largely due to its innovative and sophisticated use of instructional methods and media – it was not, in fact, the first. The world's first open distance teaching university was established in 1946 in South Africa. Based in country's capital Pretoria, the University of South Africa (UNISA) was 'open to all', and remained so even during the Apartheid era (1948-1994), providing educational access to large numbers of black and so-called 'colored' students who were mostly excluded from the educational and political system, along with white students, who were a minority in the country (ibid.).

Nevertheless, it is the founding of the British Open University in 1969 that marked the beginning of a new era for open distance education, one of increased prestige, pedagogical innovation and academic excellence. Sophisticated course offerings that utilized new media technologies, expansive student support services and systematic systems evaluation all contributed to the expansion of 'open education' at the postsecondary level. Largely inspired by the success of the OU, a number of similar institutions began cropping up around the world during the 1970s and 1980s, such as Canada's Athabasca University (est. 1970), Spain's National University of Distance Education (est. 1972), Germany's FernUniversität Hagen (est. 1974), Israel's Open University (est. 1974), China's Open University (est. 1979) and India's Indira Gandhi National Open University (est. 1985).

What is noteworthy about these institutions is that, despite all of them being 'open' universities, they operate on vastly different models and scales (Guri-Rosenblit, 2012). Some were designed to serve millions (e.g., the Indira Gandhi National Open University in India and the Open University in China), while others only teach a few thousand students. Several adopted an open admission policy (e.g., the OU, Athabasca University and the Open University of Israel), while a few require the same or similar entry requirements as their conventional counterparts (e.g., the Open University of China, FernUniversität Hagen). Some charge very modest tuition/fees, while others come with a slightly heftier price tag. None of them are completely free, although in countries were education is highly subsidized, they are rather inexpensive. At the same time, in countries were public higher education is free, open universities are significantly less 'affordable'. In these contexts, however, open universities emphasize 'openness' as 'freedom of choice' and 'freedom of entry'. Because countries with free education systems tend to base university admission on rather demanding exams, many people are excluded from the programs and institutions of their choice. Thus, open universities provide an alternative means for them to pursue courses and degrees that would not otherwise be available to them.

This historical reconstruction of 'openness' provides a broadened understanding of the concept beyond the techno-centrism and techno-idealism of current discourses, and allows us to ground open textbooks - and OER more broadly – in earlier incarnations of the phenomenon. As this historical account makes evident, open education is as much about technological, as it is about cultural, political and economic issues. Open education initiatives have often made use of the latest technology (be it the postal system or the Internet), yes, but there has always been a broader social and institutional context that has shaped their development and, often, led to their decline. Furthermore, history shows that even before the onset of the Internet, people have been hungry for open access to learning and for flexible alternatives to rigid and often exclusionary educational systems and curricula. Openness, moreover, has rarely meant 100% free.

Recent debates around MOOCs and open textbooks have largely framed openness in terms of cost and technological features, failing in most part to place these artifacts – and the practices surrounding them – in an historical context (for a notable exception see Peter, 2013). This section offers a corrective to the ahistorical narrative surrounding OER, and open textbooks in particular. The following section reviews how open education was transformed through rapid technological developments from the 1980s onward.

3.3. Open education from the 1980s on: free software, open source software and the 'technological turn' in openness

As the previous section demonstrated, the history of open education dates back way before the advent of computers and the Internet. However, rapid developments in information and communication technologies during the 1980s, along with, in particular, the rise of the free and open source software movements, reframed how 'openness' in education and its potential were understood. During that time, we observe a fundamental shift in how the concept is framed in public discourse and in the research literature (Farrow, 2017; Rolfe, 2016). Earlier incarnations of open learning and open education understood openness within a broader social mission, and saw its primary role as fostering civic engagement and democratic citizenship by, for instance, supporting the learner's autonomy, critical-thinking ability and self-determination. From the early 1990s onward, openness is increasingly discussed in terms of access to technological tools and resources, and by the early 2000s much of the debate had moved on to licensing, technical and implementation issues (Rolfe, 2017; Weller, 2014). Today, ‘open’ in education is largely discussed in terms of the ability – or not - to use, create, edit, and share content under open licenses and through social media and digital tools (Saadatmand & Kumpulainen, 2014).

Open education in terms of its most recent developments cannot be separated from the development of open systems and the history of free software, open source, open access and open content (Iiyoshi & Kumar, 2008; Kelty, 2008). The concept of free software was born in the early 1980s out of the desire to protect user's rights to freely access and modify software. In the 1950s and into the 1960s almost all software was produced by academics and corporate researchers working in collaboration, often shared as public-domain software. However, during the late 1970s, when computers began spreading in the business sector, companies begin charging for software licenses and imposing legal restrictions on new software developments, now seen as assets, through copyrights, trademarks, and leasing contracts. In 1983, dismayed by the increasing commercialization of operating systems (and in particular with Unix and its components), Richard Stallman, then at MIT's Artificial Intelligence Laboratory, launched the GNU (“GNU’s not Unix”) Project to write a complete operating system that would be free from constraints on use of its source code. Soon after, in 1985, Stallman founded the Free Software Foundation and published an essay explaining the importance of free software:

> What does society need? It needs information that is truly available to its citizens—for example, programs that people can read, fix, adapt, and improve, not just operate. But what software owners typically deliver is a black box that we can’t study or change. Society also needs freedom. When a program has an owner, the users lose freedom to control part of their own lives. And, above all, society needs to encourage the spirit of voluntary cooperation in its citizens. When software owners tell us that helping our neighbors in a natural way is “piracy”, they pollute our society’s civic spirit. This is why we say that free software is a matter of freedom, not price. (Stallman, 1994)

As Stallman (1996) notes, the word ‘free’ in ‘free Software’ refers to ‘freedom’ to distribute and change – as well as freedom to cooperate with others in using it – rather than ‘free of charge.’ Therefore, “you should think of ‘free’ as in ‘free speech,’ not as in ‘free beer’.” Specifically, software is considered free if its license grants the following freedoms to its users:

- Run the program as they wish, for any purpose.
- Modify the program to suit their needs. (To make this freedom effective in practice, one must have access to the source code, since making changes in a program without having the source code is exceedingly difficult.)
- Redistribute copies, either gratis or for a fee.
- Distribute modified versions of the program, so that the community can benefit from your improvements.

Thus, what makes software ‘nonfre’ (proprietary) is if it restricts any of these four freedoms, thereby exerting control over the user (Pomerantz & Peek, 2016). Stallman, essentially, believes that software is a fundamental infrastructure and should thus be shared both on ideological and pragmatic grounds (Adams & McCrindle, 2008). He also views controlling a software as a part of a power struggle between common citizens and software companies – a struggle whose terminology is almost identical to critical ideologies like Marxism (Stallman, 1996):

> When users don't control the program, we call it a “nonfree” or “proprietary” program. The nonfree program controls the users, and the developer controls the program; this makes the program an instrument of unjust power.

Therefore, non-free software is considered to be an injustice to its users. However, the political philosophical stance articulated by the Free Software Foundation was apparently off-putting to business – and business oriented – people and by the late 1990s, a younger generation of free software advocates, including Eric Raymond and Tim O'Reilly, became concerned that the anti-proprietary (i.e., anti- business) sensibility of the Free-Software Foundation hampered the wide-spread adoption of free software (Pomerantz & Peek, 2016). These concerns gave birth to the open source software movement.

In 1997 Eric Raymond, then a free software developer, wrote "The Cathedral and the Bazaar" (1999), a highly influential essay which contrasts two different development free software development models. "The Cathedral" refers to a top-down development model where a small group of developers produce the code, exemplified by the development of GNU Emacs and the GNU Compiler Collection (GCC). "The Bazaar," on the other hand, refers to a model in which code is developed publicly over the internet, as was the case for the development of the Linux kernel. The essay's central argument is that the Bazaar model is inherently more effective at finding and resolving software bugs, as more people are able to view, test and scrutinize the code. In contrast, Raymond claims that an inordinate amount of time and energy must be spent hunting for bugs in the Cathedral model, since the working version of the code is available only to a few developers. Thus, Raymond argued, utilizing a community-driven, bottom-up development process based on peer-review and transparency, results in better, more flexible and more reliable software. This development method came to be known as open-source. Shortly thereafter, Raymond and Bruce Perens founded the Open Source Initiative (OSI) to encourage both the use of the new term as well as the spread of open-source principles. OSI also developed the Open Source Definition—a list of ten principles which a software's license must adhere to for it to be considered open-source (OSI, 2007):

1. *Free Redistribution* - The license shall not restrict any party from selling or giving away the software as a component of a larger software distribution containing programs from several different sources.
2. *Source Code* - The program must include source code, and must allow distribution in source code as well as compiled form.
3. *Derived Works* - The license must allow modifications and derived works, and must allow them to be distributed under the same terms as the license of the original software.
4. *Integrity of The Author's Source Code* - The license may restrict source-code from being distributed in modified form only if the license allows the distribution of "patch files" with the source code for the purpose of modifying the program at build time.
5. *No Discrimination Against Persons or Groups* - The license must not discriminate against any person or group of persons.
6. *No Discrimination Against Fields of Endeavor* - The license must not restrict anyone from making use of the program in a specific field of endeavor.
7. *Distribution of License* - The rights attached to the program must apply to all to whom the program is redistributed without the need for execution of an additional license by those parties.
8. *License Must Not Be Specific to a Product* - The rights attached to the program must not depend on the program's being part of a particular software distribution.

9. *License Must Not Restrict Other Software* - The license must not place restrictions on other software that is distributed along with the licensed software.
10. *License Must Be Technology-Neutral* - No provision of the license may be predicated on any individual technology or style of interface.

Because the definitions of open-source software and free software share similarities – in particular, with regards to modification and redistribution of software – and because they are often used to describe the same software, the two terms have come to be used interchangeably. As well, it is often said, outside of these communities themselves, that differentiating between free software and open-source software is merely philosophical rather than practical, and that the difference between the two terms themselves is mainly a matter of marketing rather than substance. The term FOSS, for ‘free and open-source software,’ and even FLOSS, for ‘free/libre/open-source software’ emerged as ways to encompass all approaches to non-proprietary software.

For the free software community, however, the terms ‘open-source’ and FOSS don’t fully convey the ethical and political importance of the movement and the potential long-term social problems caused by nonfree/ nonlibre software. They argue that the open-source movement (and the OSI) are too concerned with promoting the practical benefits of non-proprietary software (including its profitability and the efficiency of a community-driven development model), and not concerned enough with the ethical issue of restricting users’ rights to change and improve code on their own terms (Klang, 2005; Stallman, 2007). Morozov (2014) has even suggested that O’Reilly and his media/ conference empire “hijacked” Stallman’s free software movement and turned it into the more corporate-friendly open-source movement. From there, Morozov argues, O'Reilly went on to redefine web freedom as freedom for companies like Google to do whatever they want online, and to redefine open government not as a movement for transparency and accountability but as the need to give free data sets to for-profit companies.

Despite these tensions, the free and open-source ethos of transparency and collaboration gradually extended into different realms, re-defining how people interact and collaborate way beyond the context of software development. In the world of education, these movements motivated educators to start creating and sharing, since the mid 1990s, educational resources over the Internet, which came to be known as learning objects (1994), open content (1998) and open courseware (2001). Interest in learning objects (LOs) emerged in the mid 1990s, with the promise of creating digital resources that could be used and reused in different contexts by different instructors/organizations. The term is contested and has been used to describe everything from software tools, to media files, to textbooks, to entire curricula (Churchill, 2007; Friesen, 2001; Sosteric & Hesemeier, 2002; Wiley, 2000). Even after more than 20 years, there is still no commonly accepted definition of what precisely constitutes a learning object, and LOs been variously termed information objects, reusable learning/information objects, intelligent objects, content objects, media objects, knowledge objects and learning resources, among others. However, they are generally understood to be digital entities, deliverable over the Internet, which are customizable, reusable and easily interoperable with other learning components.

Learning objects were heavily promoted in the educational community in the 1990s and early 2000s, particularly in the fields of e-learning, instructional design, cognitive science and information systems. While the initial idea came out of US military-funded training research (Friesen, 2004), LOs quickly came to be seen as a promising way to facilitate the growth of online and distance learning through the creation of small instructional components that could be stored in public repositories and adapted to fit a number of learning management systems and e-learning environments. The term ‘object’ in ‘learning object’ has clear origins in ‘object oriented’ programming, design, analysis and theory (Robson, 1999; Bratina, Hayes, Blumsack, 2002), which values the creation of self-contained modular components that can be reused in multiple contexts. The goal of an object-orientated approach in LO design was to enable reuse of educational materials for faster, more efficient development of future content. Thus, definitions of LOs have tended to highlight “(either directly or indirectly) modularity as a technological and design attribute for the object and its content, emphasizing the ‘self-contained,’ ‘building block’ or ‘object-oriented’ nature of the technology.” (Friesen, 2009, p2)

It was believed that in order to facilitate reusability, LOs had to be designed at an appropriately granular level, i.e. information had to be broken down to the smallest ‘nugget’ of content related to a specific learning objective. Moreover, for the learning object to be reusable in as many instructional contexts as possible, it was supposed to be as free of specific context (audience, place etc.) as possible. This led LO advocates and designers to frequently refer to these objects as ‘context-free,’ ‘pedagogically neutral’ or ‘pedagogically agnostic,’ a claim that has been heavily criticized in the educational literature (e.g. Conole, 2002, Wiley, 2002; Friesen, 2004). Besides reuse, another important characteristic of LOs is interoperability, i.e., the ability of different objects to interact and communicate with each other and existing networks and systems. To facilitate interoperability of content and systems, the Learning Technology Standards Committee (LTSC) of the Institute of Electrical and Electronics Engineers (IEEE) formed in 1996 to develop and promote instructional technology standards (Wiley, 2002). Soon after, other initiatives and organizations (e.g., the Instructional Management Systems (IMS)

Project) jumped on board and began developing technical and metadata standards to support the broad deployment of LOs.

Learning objects are often mentioned as the precursor to OER, and the discourse surrounding them bears striking similarities to the one we've seen emerge over the past few years around open courseware, MOOCs and open textbooks:

> [E]ducators and learners alike could have "anytime, anywhere" access to vast stores of high-quality, proven-effective learning objects to meet a wide array of training and educational needs. Instructors could assemble selected learning objects, customizing them according to student needs and characteristics. Students could access the learning objects on adaptive learning management systems, tailoring the activities according to their personal preferences and individual learning styles. Learning object repositories would serve a range of formal and informal learning needs, providing students with resources for lifelong learning, while promoting educational opportunities and success. To ensure flexible, ubiquitous availability of these resources, learning objects could be accessed in a variety of ways, including from desktop and laptop computers, tablets, and mobile devices. (Moisey & Ally, p. 316)
>
> From an organizational point of view, learning objects allow for efficiencies, avoiding duplication of effort between instructors and among educational institutions, and promoting more consistent instruction within and between courses. (Moisey & Ally, p.320)

Yet, despite the vision in terms of their potential to develop an 'educational exchange economy', the predicted expansion in the creation and use of LOs failed to materialize. In the mid 2000s, the term fell out of favor, as instructors discovered the actual time savings and reusability to be much less in practice than advertised (Metros, 2005; Sclater, 2016; Weller, 2014). Some scholars speculate that the reason learning objects failed to fulfil their potential was that the movement remained too focused on systems engineering techniques and standardization processes, paying inadequate attention to instructional design paradigms, existing educational practice, and the heterogeneity of educational activities in general (Bennett & McGee, 2005; Metros, 2005; Weller, 2007; Wiley, 2002). Others have pointed to implementation barriers that are also encountered in the OER arena, such as: ambiguity of definition; difficult-to-navigate repositories; lack of LOs in some disciplines; poor quality LOs; inappropriate granularity; lack of a common system and skills for creating metadata; lack of institutional rewards for designing/ implementing LOs; copyright and intellectual property concerns; and attitudinal barriers, particularly lack of confidence in the scholarly and instructional adequacy of the created learning materials and an unwillingness to share them (Boyle, 2009; Koppi et al., 2005; Metros, 2005; Moisey et al, 2006; Nash, 2005; Neven & Duval, 2002; Polsani, 2003).

Meanwhile, another movement was gathering steam, one that also espoused the notion of shared learning resources, but which placed less emphasis on notions of standards and modular design and which was, as well, less commercially minded. Inspired by the ideals and principles of open-source software, the open content movement took a major feature of open-source engineering – the open licenses applied to open-source software that enabled community driven improvement of the software code – and applied it to educational content. The idea behind publishing open content is that anyone can reuse the content, distribute it freely, modify it and redistribute it. In this way, the content can be improved upon and knowledge is made freely available for the common good. The term 'open content' was coined by David Wiley who launched the OpenContent project in 1998. Wiley argues that the meaning of 'open' in open content is just like the meaning of 'open' in daily understanding. Like a door, it can be 'widely open', 'half open,' or 'a little open.' The extent of the rights the creator wants to grant to the users defines how open the content is. In other words, according to Wiley the openness of content is measured according to the rights granted to a user of the content. The primary usage rights to open content are expressed in the 5Rs Framework: Retain, Reuse, Revise, Remix, Redistribute (see also, Chapter 2, section 2.4.3).

The late 1990s/early 2000s also marked the beginning of another major initiative in the world of open education, that of open courseware. Open courseware are course lessons (incl. lecture recordings, syllabi and class notes) created at universities and published for free via the Internet. MIT was the first university in the US to announce that all of its lecture materials were going to be uploaded and made public in 2001, an effort that later became known as MIT OpenCourseWare (OCW). The concept of MIT OpenCourseWare grew out of the MIT Council on Education Technology, which was charged with determining how MIT should position itself in the distance learning/e-learning environment. MIT OpenCourseWare was then initiated to provide a new model for the dissemination of knowledge and collaboration among scholars around the world, and contribute to the 'shared intellectual commons' in academia. The movement was soon reinforced by the launch of similar projects at Carnegie Mellon University, Yale, Stanford, the University of Michigan, and the University of California, Berkeley. Today, more than 250 universities worldwide offer open courseware, including institutions in China, Pakistan, India and Japan.

It is worth noting the tremendous cost associated with implementing and sustaining open courseware projects in terms of both manpower and computing resources. As of 2018, the annual cost of running MIT OCW was about $2.7 million. As well, the initiative has been faced with logistical challenges presented by determining ownership and obtaining publication permission for the massive amount of intellectual property items that are embedded in the course materials of MIT's faculty, in addition to the time and technical effort required to convert the educational materials to an online format. It is therefore not surprising, perhaps, that it has been overwhelmingly private and elite institutions with large endowments that have invested in open courseware projects.

Despite these issues, OCW is an important precursor to open textbooks and is often credited for spurring the global OER movement (e.g., Havemann, 2016; Johnstone, 2005; Rhoads, 2015; Smith & Casserly, 2006; Watters, 2011). In the years following the launch of MIT OpenCourseWare several other initiatives emerged based on the concept of making learning materials widely available to the public via the Internet. In 2006 Khan Academy started making K-12 educational videos available on YouTube, iTunes U was launched in 2007 to offer downloadable collections of free educational content through the iTunes Store, and that same year TEDx launched a website to feature videos from its widely inaccessible conferences to the general public free of cost. Yet, none of these initiatives captured the public imagination quite the way Massive Open Online Courses (MOOCs) did.

MOOCs emerged in 2008 in Canada, at the University of Manitoba, as an experimental method of exploring the possibilities of networked learning. However, they became the subject of media and commercial interest in 2012, when Stanford University offered a MOOC on Artificial Intelligence, enrolling 160,000 students. Not surprisingly, courses that were enrolling hundreds of thousands of students attracted much attention. In addition, some big name institutions such as Stanford University, Harvard and MIT became associated with the MOOC phenomenon. MOOCs were glamorized by their founders at Udacity, Coursera, and edX as the technological revolutions that would indeed change higher education. In her 2012 talk at TED Global, Daphne Koller, co-founder of Coursera, argued that such courses "would enable a wave of innovation, because amazing talent can be found anywhere. Maybe the next Albert Einstein or the next Steve Jobs is living somewhere in a remote village in Africa. And if we could offer that person an education, they would be able to come up with the next big idea and make the world a better place for all of us." That same year, Sebastian Thrun, co-founder of Udacity, famously predicted that in 50 years there would be only 10 higher education institutions. (Leckart, 2012)

Certainly, the idea of MOOCs democratizing education by providing Ivy League-caliber education to "anyone, anywhere, for free" made for a great headline. As a result, the media bought into the hype and run several stories predicting the end of the university as we know it (Friedman, 2013; Larson, 2013; Leckart, 2012; Lewin, 2012; Pappano, 2012). Significant investments of capital were made mostly by private investors and venture philanthropies into MOOC companies. These investors likewise fueled the hype of MOOC technology. Lastly, education policymakers and university trustees took notice and thought they found a solution to their education funding woes and pushed for major new MOOC initiatives in places such as San Jose State University and the University of Virginia – both of which were surrounded in controversy. Soon thereafter, the backlash began.

In the years that followed, the potential of MOOCs to 'disrupt' the higher education space was repeatedly called into question, and by 2015 it was clear that MOOCs were not going to live up to their proclaimed potential. Common criticisms of MOOCs included the high student-to-teacher ratio, low completion rates and the lack of a "real college experience" (Bellanger et al., 2013; Miller, 2014; Reich & Ruipérez-Valiente, 2019; Sandeen, 2013). In addition, MOOCs were criticized for catering to students who already had access to high-quality learning resources (Hollands & Tirthalli, 2014; Fowler, 2013; Laurillard, 2014), for failing to provide support mechanisms to struggling learners (Dynarski, 2018; Smith Jaggars, 2015; Stober, 2015) and for their extremely low retention rates (Breslow et al., 2013, Ho et al., 2014, Jordan, 2014; Kolowich, 2013).

As of 2018, two of the three original MOOC providers, Coursera and Udacity have largely moved out of the higher-ed space. Udacity is currently focused on workforce development and Coursera on K-12 teacher training. And, while currently more than 800 universities worldwide offer MOOCs, these courses have turned to be only a minor achievement in terms of revolutionizing educational delivery and widening access to post-secondary education. In fact, what the evolution of the MOOC highlights, is the remarkable persistence of traditional methods of higher education. Despite claims that MOOCs would bring on the demise of campus-based, face-to-face, small-lecture type education, a traditional university education remains the norm and the number one choice for young adults around the globe. MOOCs reveal how a quality education in a technology-driven society is more valuable, not less. As Pope (2014) aptly noted:

> For all the hype, MOOCs are really just content—the latest iteration of the textbook. And just like a book on a library shelf, they can be useful to a curious passerby thumbing through a few pages—or they can be the centerpiece to a well-taught course. On their own, MOOCs are hardly more likely than textbooks to re-create a quality college education in all its dimensions.

In other words, MOOCs are delivery methods – not changes in curriculum. Thus, according to Pope (ibid.), if we want to change education, we have to change how we think about teaching and content.

Another important development in the MOOC movement has been the shift away from free towards a 'fremium' model of access. Over the past few years, what is 'free' (and 'open') in Massive Open Online Courses has consistently shrunk. Originally, the entire course and associated features, like discussion boards and assignments, could be freely accessed by anyone. Some providers even offered free certificates upon completion. Now most major MOOC providers have put certain aspects of the experience behind a paywall (e.g., graded homework, quizzes, credentials) and offer some courses that are completely paid. Both of these developments – i.e., the move away from higher education to professional training, and the monetization of content – are important for understanding and, perhaps, to an extent predicting the developmental trajectory of open textbooks.

My point here, is not to discredit MOOCs or label them a 'failure,' as several commentators have done (Fellingham, 2018; Newton, 2018; Shahzad, 2017; Warner, 2017; Young, 2017). Thinking about technology in terms of set outcomes, in terms of 'success' and 'failure', 'good' and 'bad', is not particularly useful for understanding the role it plays in education and society more broadly. Moreover, commercially these companies have proven tremendously successful. For example, Udacity made $70M in 2017, up from $29M in 2016, while Coursera's 2017 revenue is estimated by Class Central at around $100M. MOOCs are a 'failed' product only insofar as they did not achieve what they set out to do: fundamentally change the nature of the university. As professional development tools, MOOCs have found their niche – it appears – among K-12 teachers and in the corporate world (Cuban, 2014; Morrison, 2016; Wells, 2013). Where MOOCs ran into trouble was when administrators and legislators (and, to some extent, educators) saw them as a low-cost credit-bearing replacement for traditional college courses – i.e., as an elegant and relatively painless solution to rising college costs and widening education gaps. What they soon discovered, however, was that increasing access to educational resources was not enough to improve educational outcomes.

In fact, the students these technologies were purportedly designed to serve (e.g., nontraditional, remedial, at-risk), were the ones it turned out they couldn't. Remarking on a failed pilot integrating Udacity MOOCs into math instruction at San Jose State University, co-founder Sebastian Thrun said (Chafkin, 2013):

> These were students from difficult neighborhoods, without good access to computers, and with all kinds of challenges in their lives. It's a group for which this medium is not a good fit.

These students, in other words, needed alternative sources of support to guide them through the learning process and provide them with individual feedback and assistance, which went fundamentally against how MOOCs were 'supposed' to work. Thus, what the San Jose State 'experiment' (and MOOCs more broadly) demonstrated, was that broadening access to higher education does not necessarily mean real higher education opportunity for all. I note this, because similar assumptions underpin the open textbook project, i.e., that educational inequity is ultimately about access (lack of affordable textbooks) and that by increasing access (giving students free textbooks) divides will be bridged. However, scholars of information technology have long argued that, rather than 'fixing' social divides, technology oftentimes reproduces and/or reinforces them (Castells, 2000, 2002; Hollands & Tirthalli, 2014; Lohr, 2018; Posner, 2017; Selwyn et all. 2001; Srinivasan, 2018). Open textbooks, while in theory increasing degrees of 'openness' in education, could actually widen rather than bridge the digital and educational divides between students, through the increasing sophistication in technologies and the competencies expected of learners. The move away from print toward inclusive-access and digital-only solutions (incl. digital-only or digital-first OER), which is often forced by those higher up and not fully supported by educators (e.g., Douglas-Gabriel, 2018; Lloyd, 2014; McKenzie, 2019), compounds this issue as well. This challenge is explored in more depth in Chapter 6.

3.4. Ed-tech and discourses of disruption

> [E]d-tech—at least its manifestation as a current blend of venture capital exuberance, Silicon Valley hype, philanthropic dollars, and ed-reform policy-making—tends to avoid annals. That is to say, ed-tech today has very little sense of its own history. Everything is "new" and "innovative" and "disruptive." It's always forward-facing, with barely a glance over its should at the past—at the history of education or the history of technology. No one had ever thought about using computers in the classroom—or so you might glean if you only read the latest marketing about apps and analytics—until this current batch of philanthropists and entrepreneurs and investors and politicians suddenly stumbled upon the idea circa 2010. (Watters, 2017)

Proponents of open education frequently position it as a radical alternative to existing forms of education. Whether it is MOOCs replacing the need to study for a program at a 'brick and mortar' campus with a pick and mix selection of "the best online courses from the best professors around the world" (Friedman, 2013) or open textbooks solving the textbook affordability 'crisis', the proposal is that new forms of openness are poised to solve the problems of educational access; to 'democratize,' 'unbundle,' and/or 'streamline' the system; and to provide better, faster and cheaper learning (e.g., Benkler, 2005; Butcher & Hoosen, 2012; Crouch, 2010; Jhangiani & Biswas-Diener, 2017; Tuomi, 2006).

Anant Agarwal, an MIT professor and the entrepreneur behind edX, the MOOC provider developed by Harvard and MIT, has referred to open education as "the single biggest change in education since the printing press." (Rosen, 2012) Open education advocate David Wiley and others have suggested that by "empowering [individuals] and leveling [the playing field]" open education has the potential to fundamentally change "the structure and practice of higher education." (Wiley & Hilton III, 2009) Meanwhile, UNESCO (2012) has lauded openness as "key to the building of peace, sustainable social and economic development, and intercultural dialogue." Along these lines, it has been frequently argued, open textbooks will 'revolutionize' educational provision by saving students millions (and, even, billions) of dollars (Allen, 2018; Student PIRGs, 2015; Vitez, 2018), improving retention and learning outcomes (McKenzie, 2018; Wiley, 2008), and empowering faculty to regain control over their instructional materials (Hewlett Foundation, 2012; PSU, 2019; Williamson, 2017; Young, Daly & Stone, 2017). In doing so, open textbooks will help fix the "nebulous problem" (Weller, 2016) of broken education.

This is 'the Silicon Valley narrative' of open education, which is the story that the technology industry tells about society (Hendrick, 2018; Weller, 2014; Peter, 2013). The Silicon Valley narrative invokes themes like 'innovation' and 'disruption,' privileges the 'new' over the 'old' and suggests that things are perpetually in need of a technological upgrade (Weller, 2014). Education, for instance, is perceived as slow, ineffective, resistant to change and old-fashioned (ibid.). Thus, the Silicon Valley narrative about education, which repeatedly states that the current higher educational model is broken, that universities haven't changed in hundreds of years, and that now, things are 'finally' bound to change with the help of technologically driven solution - including open textbooks, artificial intelligence and adaptive courseware - that will radically transform the education space. With the help of these 'innovations,' learning will not only become better, faster and cheaper, but also more democratized. In the case of open educational resources (e.g., MOOCs, open textbooks, open courseware) in particular, the proposal is that new forms of openness will transform education by sweeping away the constraints of physical sites and objects of learning, and solving the problems of educational access, lacking student engagement and low degree completion.

For a long time, open textbooks resisted the Silicon Valley narrative. Early open textbooks were written by individual faculty, shared on personal websites, and were overwhelmingly 'low-fi' in nature. There was no grand agenda or narrative that shaped their creation – educators simply created these resources because they couldn't find a commercial text that fit theirs and their students' needs, and saving their students some money was a nice bonus. The success of initiatives like OpenStax, however, changed that. As open textbook adoptions have increased, so has the need for supplementary resources that complement the core texts, especially in STEM fields were instructors rely heavily on auto-graded homework systems and other add-ons. Meanwhile, textbook publishers have been diversifying out of print for a while and investing less and less into the editorial (and content) side of things overall. Instead, they have pivoted toward the provision of software and technology services (e.g., learning analytics, personalized courseware etc.). For publishers and textbook companies, OER (i.e., free educational content developed by experts) solves the issue of having to continuously develop new, professional-grade content, freeing them up to focus on software development, testing and delivery. As a result, the OER market has come to be dominated by a distinctly techno-centric narrative of educational change where, yet again, external forces (i.e., publishing and tech companies) come to save the day by providing the types of 'innovative,' 'disruptive' and 'transformative' solutions that the 'conservative' and 'old-fashioned' institutions of higher education simply can't deliver (see next Chapter for an extended discussion on this issue).

This narrative isn't new, nor is it exclusive to the realm of OER. The history of public education in the US, particularly in the 20th century, is deeply intertwined with various educational technologies – from film to television to computers – that are often promoted as improving access or as making an outmoded system more 'modern.' Meanwhile, curriculum and generally education are depicted repeatedly as technologically primitive cultures that increasingly become vulnerable to the rationality of 20th and 21st century science and technology (Petrina, 2002). The dream, as Ferster (2014) has pointed out, has always been 'Fordist' in nature – a mass production dream which attempts to replace the classroom teacher with some sort of machine substitute that can deliver educational objectives with the same outcomes as a human, but with greater efficiency and less cost. “Within the next twenty years,” behavioral psychologist Sidney Pressey proclaimed in 1933, “special mechanical aids will […] bring about in education something analogous to the Industrial Revolution” (Pressey, 1933, p. 582-583):

> There must be an ‘industrial revolution’ in education in which educational science and the ingenuity of educational technology combine to modernize the grossly inefficient and clumsy procedures of conventional education. Work in the schools of the future will be marvelously though simply organized, so as to adjust almost automatically to individual differences and the characteristics of the learning process. There will be many labor-saving schemes and devices, and even machines--not at all for the mechanizing of education, but for the freeing of teacher and pupil from educational drudgery and incompetence.

Pressey was one of the first education psychologists to develop a ‘teaching machine’[13] and to try (unsuccessfully) to bring that machine to market. He assembled from an old typewriter parts a device he called the Automatic Teacher, which presented the student with a series of multiple-choice questions, one at a time, arranged from least to most difficult (Oremus, 2015). Only by answering one question correctly could the student move on to the next one. Pressey’s stated goal was to relieve teachers of the onerous task of grading students’ exercises, so that they could focus on more rewarding forms of interaction. Convinced of his machine’s merits, Pressey worked tirelessly for years to improve it, get financial backing for it, and introduce it to classrooms far and wide. But educators “failed to grasp the value of automating the processes of teaching and learning,” (Petrina, p. 305) Reflecting on the whole disappointing experience in

[13] According to Benjamin (1988), a teaching machine is a wholly or partially automated device that does three things: “(a) presents a unit of information, (b) provides some means for the learner to respond to the information, and (c) [the device] provides for feedback about the correctness of the information” (p. 704). For more, see for example Cuban (1986), Ferster (2014), Niemec & Wallberg (1989) and Waddington, D. I. (n.d.).

1932, Pressey wrote: “The writer has found from bitter experience that one person alone can accomplish relatively little, and he is regretfully dropping further work on these problems.”

Figure 3.3. Pressey’s “Automatic Teacher” (source: Slate)

In the late 1950s, behaviorist B.F. Skinner revived some of Pressey’s ideas in a device of his own, called the “Teaching Machine.” Skinner’s patent for the device, filed in 1958, described it as an “apparatus for the teaching of arithmetic, spelling, and so forth.” (Skinner cited in Morton, 2015) Inspired by the Socratic teaching method, Skinner divided complex lessons into a series of small questions, each requiring a response from the student and each building on the correct response to the one that came before. Skinner’s machine required students to master one concept before moving onto the next. According to Skinner, the teaching machine had such instructional potential because it provided immediate and regular reinforcement that maintained students’ interest, as the “material in the machine [was] always novel” (Skinner, 1961, p. 387). In this way, a student’s attention could be maintained without the use of aversive controls. The efficiency of the teaching machine resulted from its automatic provision of reinforcement, individualized pace setting, and a coherent instructional sequence for the student. This same ‘mastery learning’ approach motivates ALEKS[14] and other adaptive courseware today, including OpenStax Tutor (see Chapter 5).

Figure 3.4. Skinner's machine (source: Wikipedia)

As with Pressey's machine, Skinner's version was not very successful. In a lecture delivered in 1965, Skinner reflected on the adoption and usage of his teaching machines, which he regarded as "widely misunderstood." The machines were not, he said, "simply devices which mechanize functions once served by human teachers." The aim was to make both teachers' and students' lives easier by letting a machine handle some of the rote and automated tasks involved in learning. Thus, according to Skinner, the utopian dream of simply replacing the teacher with a machine significantly misunderstands the role the instructor plays in the learning process.

[14] *ALEKS* is an adaptive learning program that includes course material in mathematics, chemistry, introductory statistics, and business. It was initially developed at UC Irvine starting in 1994 and acquired by McGraw-Hill Education in 2013. It is one of the widely used online intelligent tutoring systems in the USA. For more on ALEKS, see Canfield (2001), Oremus (2015) and Stillson & Alsup (2003).

In some ways, Skinner's and Pressey's experiments can be read as a litany of failed efforts to build the very kind of 'adaptive,' 'personalized' textbooks that are explored in this study. But they also reflect the broader trend of hope, hype and letdown that marks the history of educational technology more broadly. In *Teachers and Machines* (1986) Cuban argued that a naturalized cycle of "exhilaration/ scientific credibility/ disappointment/ teacher bashing" captures the essence of the lifecycle of educational technologies[15]. This cycle always begins with big promises, backed by the technology developers' research. In the classroom, teachers never really embrace the new tools, and no significant academic improvement occurs. This provokes consistent responses from technology promoters: The problem is money, or teacher resistance, or the paralyzing school bureaucracy. Meanwhile, few people question technology advocates' claims. As results continue to lag, the blame is finally laid on the machines. Soon schools are sold on the next generation of technology, and the lucrative cycle starts all over again. Troubled technology 'interventions' like One Laptop per Child (Keating, 2009; Robertson, 2018; Watters, 2012) and the LAUSD iPad project (Crooks, 2016, 2019; Saltinski, 2014) illustrate this cycle well, as do MOOCs and their substitution in policy and media rhetoric (and the popular imagination more broadly) with open textbooks and, more widely, personalized and adaptive learning.

Along these lines, in his history of *Teaching Machines*, Ferster (2014) argues that three core issues have arisen time and again from the earliest attempts to apply technology to education. The first issue Ferster highlights, is that of scale – that is how does one teach and correct large numbers of students. Despite common claims by technology providers regarding the effectiveness of automated remediation, Ferster points out that figuring out where a mistake

[15] See also Hendrick (2018), Mayes (1995) and Peter & Deiman (2013).

occurs and how to correct it is a complicated process that is not easily (and sometimes not at all) amenable to technological intervention. Second, educational technology seems most appropriate for a rather narrow range of educational subjects: remedial math, spelling, and grammar are particularly benefited. But higher-level learning tasks like understanding a poem, writing a research paper, or engaging in art criticism (to name but a few) remain largely outside the purview of what technology can really accomplish. Last but not least, Ferster argues, no new technology has – so far – created fundamental change in *how* education is done.[16] Instead, most technological solutions simply automate delivery of content in one form or another. These are issues that open textbooks and the systems that increasingly house them are confronted with as well. Despite the hype, evidence that the students who use open textbooks have better academic experiences and/or demonstrate improved academic performance is lacking (Hilton, 2016). Whether the development of open textbooks leads to a transformative advantage over the use of conventional resources also remains an open question.

3.5. Conclusion

This chapter has taken a deeper dive into the history and meaning of 'openness,' foregrounding the discussion in the subsequent parts of this dissertation. I have argued that in order to understand the open textbook phenomenon, we need to situate it within the broader context and history of openness in education. We also need to situate open textbooks within a broader history of educational technology – or teaching machines – in the last century and a half. The next

[16] See also: Friesen (2017)

chapter, adds additional layers to this discussion by investigating how ‘openness’ is currently understood across different groups in the open textbook movement.

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CHAPTER 4: THE SOCIAL CONSTRUCTION OF OPENNESS

> Does "open" mean openly licensed content or code? And, again, which license is really "open"? Does "open" mean "made public"? Does "open" mean shared? Does "open" mean "accessible"? Accessible how? To whom? Does "open" mean editable? Negotiable? Does "open" mean "free"? Does "open" mean "open- ended"? Does "open" mean transparent? Does "open" mean "open- minded"? "Open" to new ideas and to intellectual exchange? Open to interpretation? Does "open" mean open to participation — by everyone equally? (Watters, 2014)

4.1. Introduction

How can we understand what openness is and what its implications are? In the previous chapter, I discussed how notions of 'openness' in education have evolved over time and how 'open' has meant different things to different people at different times. I have suggested already that openness is – at least, in part – socially and historically constructed. In this chapter, I want to push the discussion a bit further by examining what these processes of social shaping look like in the current open textbook landscape. Using the Social Construction of Technology (SCOT) framework as my theoretical guide, I investigate how 'openness' is interpreted by key stakeholders in the open textbook movement and how their different perspectives – and the tensions between them – contribute to shaping the realization of local open textbook initiatives. From open textbook funders, to instructors using these resources, to publishers trying to adapt to new market conditions, different stakeholders have, I show, different and, often, competing ideas about the meaning, purpose and value of open textbooks. Moreover, because they identify and prioritize different problems that open textbooks are supposedly going to solve, they push the development of these technologies into different directions.

The chapter is structured as follows: I begin with a brief[17] overview and rationale for using SCOT in my analysis and offer a summary of my arguments and key findings. Next, each stakeholder group is presented and their views on open textbooks, and openness more broadly, analyzed and situated within the literature. My goal here is not merely to present their varying interpretations of 'open,' but to highlight the ideological tensions between them and how those give rise to different artifacts and practices in different contexts. I thus seek to draw a link between perceptions about 'openness' and the developmental processes of open textbooks. In addition, I argue that the boundaries of openness in practice are much more blurry than the theoretical boundaries of any one definition of an open artifact (e.g., an 'open textbook'). This is an argument I return to in Chapters 5 and 6. I conclude this chapter with a discussion of how the open education landscape is being reshaped by emerging for-profit initiatives and what the implications of this transformation are for how openness is understood and practiced.

4.2. SCOT and the social construction of open textbooks

4.2.1. What SCOT can tells us about open textbooks

Although studies in educational technology research will frequently look at stakeholder (e.g., faculty, students, administrators) 'perceptions' of a given technological 'intervention', the meaning and implications of these perceptions is usually only discussed in relation to adoption and feature/functionality, i.e., to how likely a user is to adopt a given technology or which features they like/dislike. Similarly, in open textbook research, the studies that have, so far, explored perceptions of open textbooks, have tended to do so in terms of comparison to

[17] For a longer overview of SCOT, see Chapter 1, section 1.4.1.

‘traditional’ textbooks, focusing on questions of quality, cost, content, features and usability. SCOT, on the other hand, places perceptions in a broader social context. In other words, SCOT aims to unveil patterns and interrelationships that ‘construct’ the technological artifact in question within a particular social context. A key method SCOT researchers use to reveal these dynamics is to look for unresolved controversies or disagreements about the meaning of specific technological artifacts, for they allow us to study technology that is still in the making. These disagreements are commonly found at the level of discourse i.e., the divergent ways in which groups of people talk about and interpret the same technological artifact.

In contrast to views proposing that the development of a technological artifact progresses in a series of linear stages, SCOT presents technological construction and use as a multi-directional process. SCOT thus provides the tools to analyze the integration of information and technology into educational environments without taking its shape and purpose for granted (i.e., in a non-deterministic way). As discussed earlier, SCOT illustrates how technology creates artifacts which rarely stay in exactly the same form in which they were first created – their developers, their users and other interested *social groups* push these artifacts to evolve in new directions. Thus, using SCOT, we come to understand open textbooks not as tools with self-evident and fixed meanings but, rather, as ‘fluid’ artifacts continuously shaped and negotiated by a range of actors, interests and systemic constraints both in their production and in their realization in different contexts.

By showing how the meaning (and, shape) of open textbooks remains interpretive, flexible and under constant negotiation both by the people producing and using these artifacts, I provide a counter-narrative to more deterministic views of educational technology as an autonomous and unidirectional driver of educational change (see Chapter 3, section 3.4*.)*[18] Moreover, I provide empirical evidence to the question of what 'openness' actually looks like on the ground (i.e., how it is, in fact, practiced). As I discuss in the following sections, the practices of creating, sharing and reusing textbooks (and other OER) in the context of Californian higher education are complex and not always as 'open' as the OER community propagates. Thus, definitions of openness based on characteristics like access, licensing and format, are not particularly useful for understanding how people 'do' open textbooks, nor do they reflect the meaning that these technologies have for users. In addition, the SCOT analysis reveals notable differences in the interpretations of two primary groups – producers and users of open textbooks, with the latter, for instance, placing significantly less value on the malleability of these resources. This confirms what is frequently argued in sociotechnical studies of innovation (e.g., Bijker & Law, 1992; Grint & Woolgar, 1997; Oudshoorn & Pinch, 2003): that the dominant version of what a technology *should do*, can be more or less at odd with its actual use.

4.2.2. Relevant social groups

The term relevant social group is used in SCOT to signify "institutions and organizations... as well as organized or unorganized groups of individuals" (Pinch and Bijker, 1984, p. 414) who are involved – directly or indirectly – in the developmental processes of a particular technological artifact, system or process. The reason for locating the relevant social groups involved in the development of a technology in SCOT is in order to analyze how each group interprets and attaches meanings to that particular technology. In this study the relevant social

[18] An in-depth discussion of technological determinism in educational research is beyond the scope of this dissertation. For an overview on the topic see Oliver (2011) and Selwyn (2010).

groups identified are the following: instructors, librarians, open textbook providers, advocacy groups, traditional textbook publishers/ ed-tech companies, college administrators, students and funders[19]. Diagram 1 illustrates these key stakeholders.

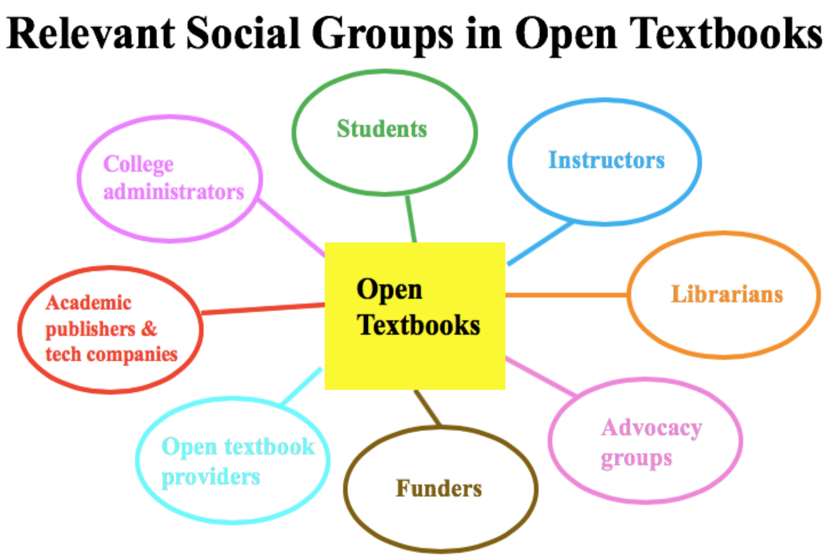

Figure 4.1. Relevant social groups in open textbooks

4.3. Perceptions of the relevant social groups

Below I analyze the viewpoints of the various social groups, along with elements and processes that have shaped their perceptions. I also discuss how perception differences are shaping the implementation process of open textbooks in the state of California, as well as its outcomes.

4.3.1. Funders

[19] While I recognize that there are other stakeholders involved as well, such as computer engineers and bookstore managers, for the sake of keeping the length of this chapter reasonable, I have decided to focus on the ones I consider most instrumental.

The open textbook ecosystem is supported primarily through funding from philanthropic, state and federal sources. Major philanthropic supporters of open textbooks include the Hewlett Foundation, the Bill and Melinda Gates Foundation and the Michelson 20MM Foundation. Governments and other funders have a major impact on how the artifacts and infrastructures they support are shaped, the nature and extent of integration and, ultimately, their sustainability and effectiveness.

Funders tend to be concerned with issues of educational equity and opportunity, particularly for underserved and at-risk populations. Moreover, they tend to be interested in how technology can be leveraged to achieve these goals. Tech philanthropists in particular, view open textbooks as both an opportunity to democratize access to education, and as an important dimension of the broader 'digitization' of higher-ed. Most philanthropic funders no longer support the creation of individual textbooks, having instead shifted their attention to the development of large-scale solutions and infrastructures that will support the use of these resources in the long term.

For example, Hewlett has recently funded the development of complete OER Degree Pathways at 38 community colleges in 13 states in partnership with the national community college reform network Achieving the Dream. Similarly, the Bill & Melinda Gates Foundation has, in the last five years, heavily invested in the development and dissemination of "next generation" adaptive courseware "targeting low income and disadvantaged learners in high enrollment undergraduate 100 and 200 level courses". Seven organizations have been funded through their Next Generation Courseware Challenge grant program, including OpenStax, the largest open textbook provider in the US, and Lumen Learning, a for-profit company that helps faculty create OER courses[20]. It is worth noting that, although the Gates Foundation has been one of the main backers of OER initiatives for the past 10+ years, their website, as of 2018, makes no mention of ‘open.’ This reveals that they are, by and large, more interested in leveraging technology to improve educational access, delivery and quality, than ‘openness’ per se.

In addition to philanthropic organizations, governments have increasingly turned toward OER in an effort to make college education more affordable and effective. Nearly half of all U.S. states have considered OER legislation in past years, while the governors of California and New York have recently provided financial support to community colleges in their respective states to help establish Zero Textbook Cost (ZTC) Degrees (also referred to as Z-Degrees). In lieu of using proprietary textbooks, Zero-Textbook Cost courses employ a mix of OER, open textbooks, links to scholarly and professional websites, resources from library databases, and multimedia lectures created by instructors. These degrees, in other words, are not confined to ‘open,’ but instead support “no cost” solutions, broadly speaking. They, thus, view openness as an option on the way to affordability, rather than an ethical and/or pedagogical imperative. At the same time, these ZTC grants do not allow zero cost designated courses to require that students purchase any ancillary resources (e.g. online homework systems, workbooks), effectively blocking potential partnerships with for-profit providers offering value-added services around open textbooks (see section 4.3.3).

As well as funding individual degree pathways, the California ZTC grant stipulates that the grantees must package and publish their degree paths in an open, shared platform, such that other community college districts in the California, and beyond, can borrow from their progress. This reflects concerns about sustainability, scalability and institutionalization raised by

[20] The other organizations include Acrobatiq, Cerego, CogBooks, SmartSparrow, and Stanford University.

philanthropists, as noted earlier. At the same time, the emphasis on sharing, transparency and reuse is very much an ‘open’ ethos, even if it is not framed as such by the state government.

Finally, it is worth noting that both state and federal funding has focused on supporting OER adoption at the community college level, which suggests that openness is viewed by governments primarily as a means for removing educational barriers, as opposed to, say, a driver of pedagogical and technological innovation, which is largely considered to be the purview of research universities.

4.3.2. Advocacy groups

There are several groups that focus on promoting open textbook use and institutionalization, including the Scholarly Publishing and Academic Resources Coalition (SPARC), the Rebus community, the Student PIRGs, College Open Textbooks, and the Open Textbook Alliance. Some advocates, such as the Rebus community, discuss openness primarily in terms of freedom through licensing – freedom to access, but more importantly to adapt, improve and redistribute the content as one sees fit. A strong proponent for the use of the Creative Commons Attribution International (CC-BY) license, Rebus seeks not only to promote the use of open textbooks, but also to maximize how users engage with open textbook content. According to the Rebus website:

> [the network’s members] share a mission to foster a vibrant OER ecosystem in which anyone can exercise the “5Rs” legal rights to: retain, reuse, revise, remix and redistribute open textbooks and other OER. The CC BY license makes it easier for all of us to achieve our objective: a world where open textbooks and OER can be easily remixed to meet local education needs.

Student advocacy groups, such as the Student PIRGs and the Open Textbook Alliance, are less concerned with the "5Rs", and tend to frame open textbooks primarily in terms of reduced costs, increased access and improved outcomes for students. According to a 2018 Student PIRG report:

> Open education aims to reshape the marketplace by moving knowledge into the commons and allowing students of all socioeconomic backgrounds and institutions to access the materials they need to succeed in class. […] When materials are switched from proprietary to open, students not only experience significant cost savings, but they understand that their academic success matters above all else, including above profits for publishers.

The belief that open textbooks can promote access, cost and equity in higher education is also echoed by the Scholarly Publishing and Academic Resources Coalition (SPARC), a global coalition "committed to making Open the default for research and education." SPARC views open textbooks as "the most effective way to reduce textbook costs." Like Rebus, SPARC is also a strong advocate for the CC-BY license. At numerous meetings of the open education community SPARC's leaders have made the point that open education is often understood in too vague a sense, and that standards of openness are often not met on the ground. These concerns have grown stronger as more and more traditional publishers and educational technology companies have started offering digital services that wrap proprietary software around existing open textbook content (see next section for a longer discussion). Nicole Allen, Director of Education at SPARC, noted in an interview with Inside Higher Ed (McKenzie, 2018):

> It's important for new actors to understand that there are a whole set of values behind OER, beyond free content.[…] Open education is intrinsically linked with the idea of inclusivity and equity. It's about removing barriers and making sure that everyone has the opportunity to participate.

Allen, however, doesn't advocate using the more "closed" Creative Commons Attribution Non Commercial (CC-BY-NC) license, instead of the more forgiving CC-BY license, in order to prevent corporate appropriation and enclosure of open educational resources. Adopting more 'closed' licenses in order to keep the for-profit sector out not only hurts the community itself by limiting what users can do with open educational content, but also outright contradicts the 'open"' ethos that advocates have sought to promote. In a Twitter thread on this issue, Allen argued:

> I believe true openness *is* a path to social justice and the public interest. Open means letting anyone use, build upon, and benefit from knowledge, often in ways we can't imagine or predict. I defend the integrity of this vision so we don't fall short of a truly open system.

At the same time, Allen was highly critical of traditional publishers integrating open content into proprietary platforms and calling the final product "open":

> I do have a problem with the same companies who drove textbook costs out of control appropriating the OER banner to frame this product as solution to a problem they created.
>
> Do whatever you want with the content - that's the point of CC BY. But don't lock it inside a platform, charge students for access, and still try and claim it's #OER.

In these remarks, Allen draws an important distinction between *using* open content and *being* 'open.' This question of what it means to *do open* and whether there's a right and wrong way of doing so, ties in with concerns about 'good' OER stewardship raised by Lisa Petrides, founder and CEO of the Institute for the Study of Knowledge Management in Education. In an interview with Inside Higher Ed (McKenzie, 2018), Petrides suggested that publishers are "by no means excluded" from the OER community. However, she noted the importance of organizations – and individuals – using OER to "sow, as well as harvest", meaning to be accountable and to give back to the open education community at large.

Overall, advocates were - with the exception of student-lead groups – more likely than other stakeholder groups to discuss openness in techno-legal terms. Their concern, however, ultimately appears to lie with ensuring the future health, vitality and sustainability of the open education movement, than with 'gatekeeping' openness per se.

4.3.3. Publishing and educational technology companies

Up until recently, open textbooks (and OER more broadly) were largely perceived as a threat by publishing and technology companies. However, there has been a very clear shift in their view of these resources, from threat to opportunity. In the last 12 months, as part of a broader move away from print to digital, publishers including Macmillan, Pearson, and McGraw-Hill have introduced digital 'textbook alternatives' that combine 'open' and proprietary content in an adaptive learning environment. As well, a number of educational technology companies have emerged, offering digital platforms that 'enhance' open textbooks, such as Lumen Learning and Knewton. Broadly speaking, the solutions these publishers and tech companies offer represent either a blend of free and premium content, or free and premium content plus platform that is accessed on a subscription basis for anywhere between $25 and $80.

While some companies like Lumen Learning (which was co-founded by OER-advocate David Wiley) have actively positioned themselves as part of the open and the textbook affordability movements, most use language that primarily highlights their expertise in learning research, instructional design and 'effective' technology implementation – although language on affordability appears across the board on company websites and in press releases/interviews. A 2018 press release from the Macmillan-owned OER curation platform Intellus Learning, suggested that the platform "makes it easy for faculty to find, adopt, and use the highest quality OER resources and deliver a customizable, *affordable* [emphasis my own] course to students." Similarly, Barnes & Noble Education notes on the website of their open courseware platform "Courseware" that the company works "to bring new solutions for *affordable* [emphasis my own] course materials." By utilizing existing open content, such as open textbooks, videos and podcasts, the companies argue, they are able to provide an effective yet affordable learning experience to students.

Primarily, however, publishing and tech companies paint themselves as premier and expert providers of an 'improved' OER user experience, for students and instructors alike. The tagline of Cengage's OpenNow platform is "the future of OER is NOW", while Barnes & Noble's Courseware platform uses the catchphrase "smarter OER, easier implementation, better learning". In carving out their space in the OER marketplace, these companies have highlighted many of the perceived weaknesses of open textbooks, and OER more broadly, such as findability, adaptability and durability. They have thus created a discourse were OER is celebrated for its flexibility, affordability and overall 'potential', but where its quality, ease of use, efficacy and malleability are questioned. Within this narrative, open content is presented as innovative, but, ultimately, not really usable 'as is', and therefore dependent on the pedagogical expertise and technological skills that these companies provide to fulfill its potential.

As Cheryl Constantini, Vice President of Content Strategy at Cengage, argued in an online interview (Cengage, 2018):

> For all the benefits of OER, there are challenges. Many instructors are skeptical about quality; it can be hard to find, maintain and sustain; it may have gaps in coverage; and it may not be available in ways that are efficient to use. We are also seeing that programs cannot simply provide OER as piecemeal or standalone content and expect the same results as a fully-developed, instructionally designed course. There are countless stories of institutions building OER courses — investing tens of thousands of dollars — with little to show for their efforts, and even less design and maintenance support to ensure the course remains relevant and functional. We help solve those obstacles. We have been developing content for over 150 years. Fortunately, we know how to design, curate, permission and ensure content quality and longevity. […] There's value in the reliability, support and service that we provide.

Similarly, Roy Kaufman, former legal director at Wiley-Blackwell and now a managing director at the Copyright Clearance Center, published an article in early 2018 titled "With Flexibility, Publishers Can Turn the OER Boom To Their Advantage", which echoed the idea that the existing OER infrastructure is messy and, ultimately, unable to provide true and long-lasting value:

> Institutions do not want to sacrifice instructional quality or efficacy at the expense of making learning materials more affordable or customizable - yet finding the right high-quality OER resource is not always easy. OER repositories such as Merlot and OER Commons have gained a lot of recognition, but provide their own set of challenges - they offer a wide range of content, but require managing diverse file formats and content types. Often the content is fragmented and not tagged to specific learning objectives […]. Even if you find OER that aligns with an instructor's learning goals, the real challenge is finding content that will support an entire course.

Thus, according to Kaufman, one of the most significant contribution publishers can make to OER is their expertise in curation. Overall, while most OER advocates and users understand 'open' to mean 'free of cost,' publishing and technology companies have argued instead for a 'low-cost' approach that utilizes their expertise, skills, resources and other infrastructure, and which will, they argue, ultimately ensure to sustainability of the OER project.

4.3.4. Open textbook providers

The providers interviewed for this study include OpenStax,[21] LibreTexts[22] and SmartHistory.[23] Although by no means all-encompassing, these are some of the most prominent non-profit open textbook providers in the United States. OpenStax and LibreTexts largely represent STEM fields and other high-enrollment introductory level college courses. SmartHistory covers intro-level art

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[21] OpenStax is the largest publisher of open textbooks in the United States. Founded in 2012 and based at Rice University, it currently offers over 35 titles for college and AP courses mostly in STEM areas, as well as in Business, Sociology, Psychology, Government and US History. Its textbooks are available in free digital formats (web and PDF) and for a low cost in iBooks, Kindle and in print. They are licensed under CC BY *4.0.* OpenStax also offers a hosting platform, OpenStax CNX, to allow free adaptation of their textbooks. OpenStax has fostered an ecosystem of over 40 for-profit and non-profit partners (companies providing computer-based homework sets, for example) that both help drive adoption and provide a way to return revenue to sustain the initiative long term. OpenStax partners create optional low-cost technology products that are integrated with OpenStax textbooks. Current partners include Barnes & Noble Courseware, Cengage, eMath, WebAssign and XYZ Homework. OpenStax has also launched OpenStax Tutor, an adaptive courseware based on cognitive science principles, machine learning, and OpenStax content. So far, it is the only non-profit open textbook provider to offer an adaptive courseware platform for its textbooks.

[22] LibreTexts is a multi-institutional, not-for-profit open textbook organization initiated in 2008 at the University of California, Davis. The LibreText project consists of 12 independently operating and interconnected libraries that host over 68,500 pages of content in a number of fields with a current emphasis on STEM. Its textbooks (or, textbook alternatives) are organized within a central environment that is both vertically (from advance to basic level) and horizontally (across different fields) integrated. Because it evolved from the ChemWiki project, which focused on chemistry textbooks, the chemistry library is currently its most developed library. LibreTexts' development approach is highly collaborative and involves participants at over 35 institutions, including the University of Michigan, DePauw University, the University of Minnesota Rochester, Mendocino College, and South Tahoe Community College. In September 2018, LibreTexts was awarded a $5 million Open Textbooks Pilot Program grant from the Department of Education funded by Congress in order to expand the range of online services available to faculty developers and student users including interactive 3D visualizations, embedded executable source code, big data informatics, the ability to include personal and class wide annotations, and intelligent coupling into learning management systems. The project is powered by Mindtouch's cloud-delivered web platform and licensed under CC BY-NC-SA.

[23] Smarthistory is a leading resource for the college-level study of art and cultural heritage. The project started in 2005 as an audio guide series for use at the Metropolitan Museum of Art, The Museum of Modern Art in New York City, and as a resource for students taking introductory art history courses at the college level. SmartHistory features videos, podcasts and teaching resources such as Syllabi and lesson plans. In addition, it distributes content via Youtube and Flickr. Smarthistory's content is curated by its executive editors and authored by more than 200 academics, curators, and staff at museums and related institutions. As of 2018, Smarthistory has published 1500 videos and essays on art and cultural history from the Paleolithic era to the 21st century that include the art of Africa, the Americas, Asia, Europe, and Oceania. The site runs on WordPress and is licensed under CC BY-NC-SA.

history, and related fields. The providers were selected to cover as broad a range of disciplines, organizational types and technical platforms as possible.

While each provider offered a slightly different interpretation of 'open,' they all viewed the integration of open educational resources into undergraduate teaching as a way to invigorate pedagogy and assist students in learning more effectively. Overall, openness was discussed as a 'disruptive' force and as an alternative to the 'one-size-fits-all' model of education, which the providers described as 'outdated.' This was something that publishers, technology companies and open textbook providers all had in common.

Moreover, all three providers described traditional, print textbooks as more or less limiting, not just in terms of cost, but also in terms of format and capabilities, and expressed their desire to provide something that isn't just an electronic version of a textbook. Thus, they talked about openness as an enabler of freedom – freedom from academic structure, outdated notions of authority, and the physicality of print. The idea of freedom is also strongly reflected in LibreTexts's tagline, "free the textbook", as well as the following statement by SmartHistory's Beth Harris:

> I think that part of what the problem is […] that we still think about textbooks. We still think about whole things that are readymade and that have a single author, or just several authors, and that is kind of a limited thing. Limited in its interactivity, limited in its use of multimedia, limited in the number of voices that are authors of it. And so the whole idea of a textbook, while textbooks are useful and have been useful, we think about it as a kind of model that we want to change and build on and expand. [Because] print is limited. Print does not have the flexibility and modularity necessary, especially if it's bound. And I think that there's an inherent sort of conservatism […], continuing to hold on to the model of a bound book. And I'm not sure how profitable that analogy remains.

Although the three providers agreed – to an extent – that there is an audience for print, at least for now, they all suggested that the future of textbooks, including open textbooks, will be digital.

The digital, thus, was seen as an essential dimension of 'open.' For some of them, however, this idea goes significantly beyond creating content and sharing it online. OpenStax and LibreTexts, for instance, have heavily invested in the development of 'enhanced learning environments,' i.e. adaptive learning systems that house open textbook content, track student activity and performance, and offer built-in opportunities to help students retain information better. The goal of these systems is not merely to increase access to learning, but to provide *better* learning primarily by utilizing data analytics and machine-learning capabilities. According to Richard Baraniuk, founding director of OpenStax, the company hopes that with their adaptive courseware platform OpenStax Tutor they will be able to increase student persistence and degree completion by providing a more personalized, flexible and interactive learning experience.

One dimension of openness that was emphasized more strongly by providers than other groups was modularity, which refers to the degree to which a system's components may be separated and recombined. In the open textbook context, modular design and organization supports remix and re-appropriation, that is, the possibility of disassembling a textbook into its components, modifying one or more of these components, and reassembling the modified components into a different textbook. By 'mixing and matching' components, instructors are able to develop educational materials that better fit the needs of their students and their specific context, the providers argued.

However, opinions differed on the extent to which they thought open textbooks actually fulfilled this promise. SmartHistory's Beth Harris argued that the "vast majority" of their audience was keen to customize their resources. On the other hand, Alana Lemay-Gibson, director of technical project management at OpenStax, and Delmar Larsen, director of LibreTexts, suggested that customization and/or remix may be significantly hampered in practice due to lack of standards, consistency and interoperability between resources created by different individuals and organizations. This difference in perception between providers might be explained by the fact that in art history (and many other humanities fields) instructors are more likely to assign a series of readings from different sources than to use a single textbook, compared to instructors in STEM fields and the social sciences, who are the primary audience of OpenStax and LibreTexts. If one is merely compiling a Syllabus by pulling together individual articles, interoperability of content is much less of an issue than if someone were to create an actual textbook, where every single component has to interface with all other textbook components, not just at the level of content, but also at the technical (e.g., encoding) and social (e.g., copyright) levels.

Larsen, suggested that the solution to this challenge would be to move everything into one system – the LibreTexts system:

> We believe that in order to really move this effort forward you need to bring everything into the same system, in the same formatting. So when you want to build a new textbook you can just grab this and that and it's just a simple copy and paste and you're ready to go. But if you have one thing as a PDF and another in HTML, and this thing is different than this other thing, it becomes more awkward to do that. If you bring it all together in the same library or a series of libraries that follow the same formatting, [so] that you can cut and paste, that will really move this forward. So a lot of our effort consist of taking existing content and integrating it into our system. […] And I think that that effort is what will be the future, to be honest.

OpenStax, on the other hand, has taken a different approach. Rather than build a single system that will house the world's entire library of open textbooks, the organization has focused on building an "ecosystem of corporate partners – including for-profit textbook publishers like Macmillan – that combine open with proprietary content, and/or offer value-added services around OpenStax's textbooks (e.g. adaptive homework systems, assessment systems and graphing calculator apps). When asked whether he was concerned about these for-profit ventures ‘hijacking,’ or altering, the open education movement, Richard Baraniuk, director at OpenStax responded that “if you truly believe in free and open and what that really means, if the publishers are doing that in a legal way, then it shouldn’t bother you. And if it does bother you, then it means you weren’t really that open in the first place.” Baraniuk went on to suggest that collaborations between for-profit and non-profit providers can be “very productive and symbiotic:”

> The reason why we are excited about [our partnerships] is that it helps get the word out about OpenStax and, as those companies make money, they are actually revenue sharing back with us. So when they make a sale from a $40 subscription system, they’re sharing roughly 10-15% back with us, so that we can sustain ourselves long-term. And that revenue is absolutely critical for us going long-term, because the problem with a lot of OER is that they try to keep money out of the equation, and if you keep money out of the equation it’s very hard to sustain the project long-term.

Daniel Williamson, managing director at OpenStax, added that their ecosystem of partners provides a “freedom of choice” that is currently not the market norm, in the sense that the core content (i.e. the OpenStax textbook) is always open and free for users, but instructors and students can choose additional services by a variety of providers to add to that, based on their specific needs.

Finally, all providers emphasized the role that philanthropic support plays – and will continue to play – in sustaining “open”. OpenStax’s David Harris suggested that “there is no model that I’ve seen that you can afford to do that high quality build, and give away the vast majority of it for free without philanthropy”. This finding is important in that it complicates simplistic notions of “open as free”, pointing to the economic infrastructure that is required to create and distribute public goods.

4.3.5. Instructors

The instructors I interviewed represent a variety of disciplines – including mathematics, biology, art history and psychology – as well as various institutional contexts, such as community colleges, state universities and private colleges. Cost-savings for students was the single most important aspect of openness from the viewpoint of instructors. In line with previous studies (Bliss et al., 2013; Schuwer & Janssen, 2018; Weller et al., 2015), it was overwhelmingly mentioned as the primary motivator for adopting an open textbook. “If I can save my students $100 or $200 I will do it. Because, if only it makes their financial burden a little better, take out smaller loans, work less, that’s what I want,” said one US history instructor at a community college in Southern California. As well, about half of the instructors interviewed remarked that they saw open textbooks as a way to undermine traditional publishers and/or as an alternative to academic capitalist modes of knowledge production. As one art history instructor noted: “I am not a capitalist, and so anything that I can do to toss a little sand in the eyes of capitalists, I’m going to do.”

While some instructors interpreted ‘open’ as ‘free on the web,’ most instructors expressed at least some awareness of Wiley’s (2015) 5R framework (i.e., retain-reuse-revise-remix-redistribute) and the idea that open “is supposed to mean more than just ‘gratis’”. Perhaps not surprisingly, instructors at institutions with clear OER policies and/or organized OER initiatives were more likely to be aware of formal definitions of open textbooks (and OER), as well as the basic technical and legal characteristics that mark them as such.

At the same time, some instructors were concerned about the equation of ‘open’ with ‘free’ in the long term, suggesting that providing free educational materials devalues the labor that goes into creating them, particularly in the eyes of college and university administrators.

“Does everything have to be free?”, one psychology instructor asked, adding that “maybe low-cost is good enough or, maybe, in some cases it’s even better”, while another noted that a priority for her is “to get the university administration to recognize the work that goes into creating an OER textbook and class, as counting toward tenure as the equivalent of a published text.”

Instructors at colleges and universities were open textbooks are embedded into textbook affordability initiatives, rather than ‘open’ initiatives, were more likely to embrace the idea of ‘low cost’ or ‘affordable’ as opposed to ‘free,’ and/or to have more fluid understandings of openness, which suggests that context and in particular institutional culture strongly shape how instructors view new technologies. This was also true of some faculty who are leading OER initiatives, or who are overseeing the implementation of OER/Z-Degree grants, which might be attributed to the fact that they have to deal with on-the-ground implementation barriers (e.g., time, technology, content availability) and set-backs that strict advocates of ‘openness’ might not be as exposed to.

In terms of characteristics such as malleability and remixability, these were not high on the agenda for the majority of instructors. Adjuncts in particular, which account for the majority of the instructional workforce at community colleges in California, were more likely to embrace the idea of pre-packaged textbook solutions that could replace for-pay textbooks with minimal input. This is not surprising given that adjuncts often teach four or more courses simultaneously at multiple institutions, and are typically not compensated for course preparation and lesson planning.

While some instructors valued the ability to make changes to a text, most of them said that they had not yet engaged in these types of practices, primarily due to time and/or technical barriers. This was also corroborated by a faculty member leading an OER awareness campaign on her campus, who noted:

> most instructors that I've talked to would much rather have a pre-packaged thing than build their own modules. It's funny that the idea of OER is that you can build your own and for some people that is a super-thing but for a lot of folks it's like "just give me the book".

In addition, some instructors expressed concern about sharing remixed and/or adapted material, because they felt that it was rushed, looked scruffy or still 'in the process of becoming.' A biology instructor attempted to create a textbook by combining sections of OpenStax's *Biology* and *Concepts of Biology* texts, said that she ultimate ended up going with a text from a different provider (CK-12) that better fit her course, because what she had created was "fast and dirty", "wasn't great" and "to clean it up would have taken a lot of time". These findings are in line with similar studies which report that instructors are less like to share modified resources if, after spending a lot of time, they find the benefits to be inadequate (Hew & Hara, 2007; Kankanhalli et al., 2005). Overall, from the interviews it appeared that in the open textbook context, unlike with crowdsourced projects like Wikipedia, the revising and remixing is happening largely offline, if at all, and the original resources are not undergoing continuous improvement.

In terms of openness as a pedagogical approach or value, awareness about the potential of open textbooks to enhance or otherwise alter teaching practices was limited. When asked directly if the adoption of an open textbook had impacted their teaching approach, more than half of the instructors reported no significant changes. Yet, almost all instructors who had engaged in authorship and/or curation of resources noted that the process had led them to rethink how they deliver content.[24]

Lastly, some adjunct faculty viewed their engagement with open textbooks as a way to increase their marketability in the workplace and/or as a way to bolster their CVs. “I hope that they will see what I’m doing here and […] that I will be recognized academically for this”, one instructor noted. While personal gain was clearly not a primary motivator for instructors, this finding questions the popular idea that open practices always are, or should be, altruistically motivated.

4.3.6. Librarians

Librarians discussed open textbooks within the broader library mission to provide information literacy training and to promote critical thinking about information in an increasingly digitized world. They also related open textbooks to educational ideas about student empowerment and lifelong learning.

More than other stakeholders, librarians talked about the importance of making ‘open’ as accessible as possible – particularly at the community college level. While they agreed that open

[24] This is in line with findings by Jung, Baure and Heaps (2017), as well as Griffiths et al. (2017). In Jung, Baure and Heaps (2017), many faculty reported little to no change in their instruction as a result of using open textbooks (52%). However, some faculty believed using open textbooks enabled positive changes in their instruction. For example, several faculty indicated they started employing student-centered instruction such as collaborative and active learning strategies as well as implementing flipped classroom methods. These instructional approaches, in turn, helped the faculty members employ different types of assessments, enabled displaying/referring to the open textbook during class, or facilitated the use of applied examples/problems. In Griffiths et al. (2017), most surveyed instructors did not report a change in their teaching approach, or differences in students’ engagement or preparation with OER. However, instructors who had taken advantage of supports for course development (e.g., library services) and who had used OER for a while, were more likely to report changes in pedagogy. An important question for future research is thus whether a combination of instructional support and experience enables instructors to take advantage of the affordances of OER (incl. open textbooks) in ways that provide meaningful and observable benefits to students.

textbooks and OER are not necessarily less accessible than traditional textbooks, several argued that accessibility isn't enough of a priority as, perhaps, it should be. They also noted that 'access' is often defined too narrowly in terms of economic barriers. According to a librarian at a community college in Orange County:

> For me it's baffling that there's so little conversation about accessibility. OER is all about making things accessible and removing barriers, so to not go that extra step and remove that extra barrier for students with special needs, even if it is just small percentage, seems very contrary to the idea of open. A barrier is a barrier, whether it's a cost barrier, or an availability barrier, or an accessibility barrier.

Two librarians working in rural community colleges in California also expressed concern about the rising popularity of highly interactive textbooks featuring 3D graphics, videos and other 'advanced' features, noting that some of their students find them overwhelming, and/or do not have the bandwidth necessary to take full advantage of them. They also noted that some of their instructors have been reluctant to adopt OER that are not readily available in a printable format, because they are concerned about students who crave a more traditional reading experience. This concern was echoed by some instructors working at minority-serving institutions as well, who framed access to print as a social justice issue.

As well, librarians questioned the idea of 'open' as a panacea, suggesting that, in some instances, it may not be possible to make everything open. To this point, they noted that some disciplines are not "very OER-friendly", due to the very nature of the object they study (e.g., English), or due to supplementary materials that are required to teach them. Going 'open' in STEM fields they argued, is particularly challenging because textbooks in these fields traditionally come with test banks (and sometimes even test generating software), lab manuals, Powerpoint lecture presentations and other resources that save instructors a lot of time.

Therefore, they are often very resistant to giving them up. As one librarian at a community college in Central California noted:

> Probably the biggest challenge that we've seen are in STEM fields, the math and science instructors they have drank the Pearson poison for so long, they have test banks and they have this very elaborate nice system with MyMathLab, where students log in, with tutorials and test banks. When you take that away, because there's a cost involved, where do you turn for these test things, where do you turn for those large systems? And there is MyOpenMath and some others, but that's not an option for everyone.

Similarly, a librarian working at a Bay Area community college noted that instructors in computer science often use programming manuals (e.g., Java) that aren't open or even free, noting that "there's just no way around that."

Another discipline that was frequently described as resistant to 'opening up,' is English. Typically, instructors in these courses assign a number of original literary works throughout the semester, many (if not most) of which cannot be found in the public domain[25]. Given the social and political climate in the US, there's a strong desire to expose students to more current ethic and minority literature that moves beyond "the dead white male perspective". Because these works are relatively new, they are subject to copyright. Hence, there is no easy way to replace them with an open textbook, and library reserves are only a partial solution, as one librarian noted:

> Of course, you can always put some books on reserve in the library, but that assumes that students are going to manage their time very effectively. And, of course, there are students who don't like to sit in the library and read, or can't, because of family or work obligations. And so, it's not that it's not possible, but that it's so restricting in terms of how they interact with the material. They wouldn't be able to highlight the book, write in

[25] A public-domain book is a book with no copyright, a book that was created without a license, or a book where its copyrights expired, or have been forfeited. Public domain books are not restricted by copyright and do not require a license or fee to use. Broadly speaking, most works in the public domain were published before 1923.

> the margins and so on. And these are things that English faculty want their students to do – they want them to interact with the text, to annotate it. You can't do that with a library book.

More than other stakeholders, librarians also emphasized the importance of sharing and re-sharing materials with the wider OER community, and saw sharing/re-sharing as an essential aspect of open practice. They noted that some faculty will create or curate free digital materials and share them with their students and, maybe, their library, but will make not deposit them into extra-institutional OER repositories for instructors from other institutions to access. One librarian suggested that the reason instructors may underestimate the value of sharing, is because they consider the textbooks (or textbook alternatives) too idiosyncratic and specific to their courses.

Some librarians also noted that lack of standards in the OER community is hampering share-ability and reusability, with two of them describing the OER world as a "Wild, Wild, West." They discussed how software and design standards enable interoperability between different textbooks – and textbook components – created by different individuals or entities. Yet, they acknowledged that reinforcing any standard also 'closes' a system to an extent and can, potentially, hamper innovation and/or localization efforts.

Finally, librarians across the board had mixed feelings about for-profit companies entering the OER market by offering value-added services wrapped around open textbooks and other open content. Overall, however, they agreed that there is a place for them, particularly as a way of increasing sustainability and supporting adjunct instructors who might otherwise not have the time and resources to make the switch to open:

> I feel that it's better than $200, so it's something. And then the other issue is, that at our college we rely on tons of adjunct labor and for them, not to completely redesign their

> courses and to have that kind of support, especially if they're working at 2,3,4 campuses, that's something. But I haven't really figured out how I feel about it, I guess.
>
> It's fine in some ways. We have some folks here who are adamantly opposed.. I think that these things take money. You know, you've got to have a system in place, and that takes funding. You need programmers, you need developers. It's a beautiful utopia to envision where you don't need that, but you really do.

Overall, librarians took a balanced approach to discussing openness. On the one hand, they embraced the ethos of 'open,' and saw open textbooks as playing a central role in promoting information access and equity for students from disadvantaged backgrounds. On the other, they were highly attuned to implementation barriers at their institutions (e.g., technical, economic and disciplinary constraints) and noted important limitations to openness as a 'panacea' or a blanket solution. Ultimately, like instructors, they viewed cost-reduction as the most important contribution of 'open.'

4.3.7. Students

Students discussed open textbooks largely in terms of cost, practicality and ease of use. This is in line with similar studies on student attitudes toward open and digital textbooks (Bliss et al., 2013; Hilton III et al., 2013; Lindshield & Adhikari, 2013). In particular students from lower socioeconomic backgrounds appreciated that open textbooks came at no cost to them. As one student stated: "the thing that I like most about [the open textbook] is that it's free! That just takes a big burden off my shoulders.. It's something less I need to worry about." Another student, who said she had to switch majors because she could not afford her Biology texts, said that it was nice to see more and more professors make the switch to "free" textbooks.

As well, all students highlighted the flexibility in terms of access and studying that open textbooks offered. Talking about her art history textbook one student said:

> I really like the (open) textbook because it's more compressed and you don't have to carry around all these books to school, and you can access it anywhere, you can go to the library and work on something, instead of having to drag your textbooks around all day. And it's easier to copy and paste stuff off of those, if you need to. Like, if you're using a direct quote in an essay you can just copy and paste it and cite it later. And I like that it's online too, because it's easier for me to read, you can enlarge the pages if the font is too small and you can enlarge images. In my political science textbook, which is also online but we have to pay for it, there's a lot of copyright stuff you can actually not copy and paste off of it, like if you need to print out, some notes out of it, you can't, it won't let you, you can just access it on the website.

It is also worth noting that none of the students interviewed (formally or informally) used the term 'open' to refer to open textbooks – even when the interviewer did. Instead they chose to call them "free," "digital" or "online" textbooks. Students at a state university with a well-known e-text initiative, tended to refer to open textbooks as "e-texts". This result warrants further study. It could be that students are merely copying the institutional discourse or the language of their instructors. This is not without consequences, however. Language determines what we see (in this case, the free and/or 'electronic instead of the 'open'), consider, and understand – as well as what we don't (i.e., the benefits of 'open' beyond cost-savings). Furthermore, if students cannot 'tell' between an open and a proprietary text beyond the fact that one is free and the other isn't, this likely means that they are employed pedagogically in the same manner.

4.3.8. College administrators

Overall, institutional administrators tended to view open textbooks mainly in terms of social inclusion, equality and widening access to higher education, which also reflects the perspective of instructors and librarians interviewed. As Leslie Kennedy, director of the Affordable Learning Solutions Initiative at the CSU Chancellor's Office, noted in a CSU press release:

> In 2017-18, faculty across the CSU saved their students $39 million in textbook costs, and I am projecting that number to be $50 million next year. […] This program levels the playing field for students, providing them equitable access to course materials on the first day of class. […] The more faculty receive support for authoring, locating and incorporating OER into their coursework, the more CSU students will have potent opportunities for academic success.

However, some administrators also suggested that in the effort to make learning materials more affordable (or free) for students, OER were unlikely to be the only solution. Gerry Hanley, Executive Director of MERLOT and Assistant Vice Chancellor of Academic Technology Services at the CSU's Office of the Chancellor, for example, stated at a 2018 textbook affordability event[26] that library resources should not be overlooked in efforts to bring down textbook costs.

Overall, open textbooks were more likely to be discussed within textbook affordability issues and policies, rather than institutional policies around 'open' (e.g., open access), particularly from administrators at state universities and community colleges. This finding is not surprising given the type of students these institutions serve. To illustrate, a systemwide report on student homelessness and food insecurity at CSU found that 42 percent of CSU students struggle with food insecurity, while 1 in 10 students has been homeless during their studies (Crutchfield & Maguire, 2018). Similarly, 61 percent of the state's more than 2 million

[26] OLC Collaborate Los Angeles, 2018

community college students are classified as very low-income and an estimated 20 percent are food insecure[27] (The Institute for College Access and Success, 2016).

In addition to viewing OER as a way to address access and equity issues, administrators – particularly at the community college level – tended to view investment in these resources as a way to make their institution more appealing to prospective students. This was particularly true for colleges with smaller student bodies and/or colleges working on building ZTC/OER degree pathways, which can be appealing to institutions looking to increase enrollment and persistence toward graduation. This finding regarding institutional gains was also found in similar studies by Jansen et al. (2015) and Schuwer & Jansen (2018).

Leaders at institutions with stakes in online and distance education, tended to identify synergies between the use of open textbooks and online/distance education provision and highlighted the potential of open textbooks, and OER more broadly, to promote lifelong learning and self-learning. At the 2018 Open Education Global Conference, in a conversation with Larry Cooperman, Associate Dean at UCI Open, he discussed open textbooks as a form of teaching provision and learning support within the context of open education more broadly and noted their potential in terms of democratizing access to information and providing education "to anyone anywhere in the world," particularly students in developing and Third World countries. At the same time, he noted the potential of resources like MOOCs and open textbooks to increase institutional visibility and prestige. These findings are in line with past studies that have examined administrator perceptions of OER and MOOCS in the US and abroad (Allen and Seaman, 2014; Hollands & Tirthalli, 2014).

[27] For more, see: Broton, K. and Goldrick-Rab, S. (2016) and/or Blagg et al. (2017)

4.4. What type of 'open'?

While in open education research and discourse, openness is largely discussed in techno-legal terms, with open licensing viewed as a necessary feature of open textbooks and the practices surrounding them, this study paints a more complex picture. The practices of creating, sharing and reusing textbooks and other OER as described by the interviewees were very diverse, yet not always as 'open' as the OER community propagates. Moreover, instructors, administrators and librarians tended to view 'open' as an option rather than the end-all and be-all, while stakeholders further removed from the implementation process were far more likely to advocate for openness as blanket solution. In addition, hardline supporters of 'open' on the ground, tended to be employed at very small institutions (e.g., with 15-20 permanent faculty in total) where perhaps innovation is easier (or at least quicker) to embed into institutional culture, and/or those working at institutions with strong administrative buy-in for OER, and thus, extensive support for OER development and implementation (e.g., technical support, faculty release time).

Institutional and cultural contexts also appeared to play a significant role in how open textbooks were perceived, and whether openness was approached from a more 'pragmatic' or 'idealistic' viewpoint. Instructors, librarians and administrators working at the community college level, were primarily, and sometimes exclusively, interested in reducing textbook costs for their students. As well, instructors and staff at institutions where open textbook adoption is driven by textbook affordability initiatives were more likely to have blurry understandings of openness, to conflate free or affordable digital materials with openly licensed materials, and/or to consider acceptable charging students a small fee for textbook or technology access. Individuals working at institutions that frame open textbooks in terms of positive freedoms (i.e., freedom to reuse, modify, redistribute etc.), on the other hand, were more likely to embrace idealistic or 'purist' notions of openness and to refuse using anything that is not 'truly open.'

In addition, there were disciplinary differences in how openness was discussed. Instructors and providers in the humanities, for instance, discussed how open textbooks allowed them to bring in different voices, viewpoints and perspectives, particularly non-Western, non-white and non-cis male ones. They also noted the potential of these resources to 'deconstruct' or redefine the canon. To this point, it is worth adding that openness as diversity was only discussed by humanists interviewed in this study.

Open textbook providers and advocates, while recognizing and fully supporting the potential of open textbooks to help reduce the financial burden of students, expressed concern about the widespread interpretation of openness to mean 'free,' or 'online,' without some of the reuse liberties the open community had originally envisaged. Concerns were also expressed about commercial interests that are now using openness as a marketing tool, and what this will mean for the future of the open textbook movement.

Overall, openness was largely discussed in terms of instructional freedoms (to modify, adapt etc.) and freedom from constraints on learning. Significantly less attention was given to the question of what students can or should be able to do once the access barrier has been removed. This is in line with findings from other studies (e.g., Cronin, 2018; Rolfe, 2018), which suggest that notions of openness as a pedagogical value and as a student-empowerment tool are not widespread in the higher-ed community.

4.5. Open textbooks meet Big Data and predictive analytics

A key notion of Pinch & Bijker's (1987) initial conception of the social construction technology (SCOT) framework, is that of *interpretive flexibility*, which describes the idea that emerging technologies can represent/ mean different things to different social groups. The capacity of a technology to absorb various interpretative frames is conceptualized as its interpretative flexibility. Interpretive flexibility is manifested both in how people interpret artifacts, in how they design them *and* in how they use them[28]. Over time, as stakeholders identify problems with a given technological artifact, modifications are introduced and new meanings embedded into the design of that artifact, until all perceived problems are resolved and a state of *closure*[29] is achieved. Bijker (1987) has argued that when there are significant differences of interpretation between the stakeholder groups, a state of closure will only be reached if a) the most dominant group 'imposes' their meaning, b) a compromise or consensus is reached among stakeholder groups, or c) more than one designs persist indefinitely.

In the previous sections, I demonstrated how different social groups attribute different meanings to open textbooks and how these meanings shape, for instance, the format, licensing and distribution of these artifacts in different contexts and settings. However, it is important to note that different stakeholder groups have different levels of power and influence. For example, it is easy to see how instructors, instructional designers and engineers directly involved in the production process of open textbooks have far greater sway than users (i.e., students) do. At the same time, those who shape and control the public discourse around open textbooks and OER are the ones to pay attention to, because they tend to shape practice via policy and commercial

[28] To clarify, in the early days of SCOT, the idea of interpretative flexibility was generally applied to the design phase of technological artifacts. However, in more recent years, the concept has increasingly been used to analyze both the design and use of technological artifacts.

[29] In SCOT, closure marks the point where controversies end and a consensus begins to emerge about the meaning of the artifact.

channels. As Peter & Deiman (2013) have argued, rhetoric and public discourse play a notable role in shaping not only the conversation around, but also the future of open practices and initiatives.

What we are seeing with open textbooks, and OER more broadly, is that for-profit publishing and technology companies are attempting to define the OER space and its value faster than the educational community. Recognizing that demand for on-demand and affordable digital education services will only accelerate, these companies have embraced open educational resources by embedding them into their own proprietary systems and platforms. As a result, they have begun shaping not only end user expectations about OER materials adoption and use, but also mainstream understandings of what openness *is* and *can be*. How these companies *do* - or say that they do – openness, which aspects of "open" they decide to highlight and which to leave out, and how their products, practices and goals are portrayed in the media will increasingly contribute to the ways in which openness is understood and realized on the ground.

Surely, openness, in the sense of an ideology and a moral imperative on the one hand, and framed by commercial interests on the other, is not necessarily at odds. Yet, commercial interests do have the potential to undermine a truly open education, as several participants in this study pointed out. This is something that Weller (2016) has discussed at length, as well. In his book 'The Battle for Open: How openness won and why it doesn't feel like victory', Weller describes a "battle" between those who promote open access to OER and related practices such as reuse, remix and redistribution, and those who view openness as a way of luring users to proprietary platforms that represent a limited work environment (e.g., tech companies, traditional academic publishers). For Weller, it is imperative that educators take the lead in practicing openness, be in terms of technology, resources or pedagogy. He warns that one of the dangers of ‘outsourcing’ openness (by relying on commercial publishers to provide platforms that house open content, for instance) is that the commercially packaged solution “becomes not just the accepted method, but the only method which is recognized” (p. 12).

As discussed in Chapter 3, this shift was observed with MOOCs, which went from experiments in connectivist learning[30] to fully-commercialized, ‘assembly-line’ type education experiences. Early MOOCs often emphasized open-access features, such as open licensing of content, structure and learning goals, to promote the reuse and remixing of resources. However, today MOOCs largely use closed licenses for their course materials and many of them have switched from a fully free to a ‘freemium’ business model, where the basic features (e.g., the course videos) are free, but users have to pay for more advanced features (e.g., quizzes, certifications). So far, the production processes of open textbooks have not been tied to Silicon Valley in the same way that MOOCs are. In fact, the majority of open textbooks available in repositories like MERLOT and the Open Textbook Library have been written and published by individual faculty without any of the infrastructure or support provided for the creation of MOOCs. Yet, the increasing migration of open textbooks into digital platforms and systems, and its effects on ‘open’ education, and educational delivery more broadly, bears striking similarities to the MOOC project.

One important issue, which remains underexplored in the open textbook literature, is the hype around ‘personalization’ and its implications for how these resources are delivered and engaged with. Personalization, which is closely tied to the promise of adaptive learning

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[30] Connectivism is a theory of learning in a digital age that emphasizes the role of social and cultural context in how and where learning occurs. The learning process in connectivism takes place as the learner feeds their knowledge through making connections with the collective knowledge of a community (Anderson & Dron, 2011). Connectivist scholars state that learning is not merely the transfer of knowledge from the teacher to the learner and does not take place in a single environment, instead they state that knowledge is transformed and transferred through the interactions of people, especially in a web environment (Kop, 2011; Siemens, 2014).

technology, has recently become a rallying cry to challenge the ‘one size fits all’ model of the traditional education system (Waters, 2014). It has also been repeatedly highlighted in the discourse surrounding open textbooks and related value-added services and systems (Young & Johnson, 2019). At its core, personalization (in the context of education) is about the idea that data collection and data analysis at scale will lead to a better understanding of different learning styles and help structure the learning process accordingly. Personalization, however, depends on data-gathering and insight-generating technologies (e.g., machine learning and analytics).

The question of who owns and controls this data, therefore, is at least as pressing as whether OER content housed inside proprietary platforms is still ‘open’ or not. While much has been written in recent years about the potential of Big Data to provide insights about how people access, use and learn from digital platforms, such data is largely locked away and available only to the companies that own these platforms. And, while instructors are provided with ‘insights’ from data for their class, that data is only a tiny fraction of what these companies and their researchers have at their disposal. In addition, instructors have no insight into the way these systems make decisions – say, about what follow-up or extra lesson will displayed if a student fails a given quiz, since companies refuse to disclose the nature and inner workings of their algorithms.

Moreover, collection and analysis of student data comes with risks and concerns of its own. In 2013 Inside Higher Ed run an in-depth story (Kolovich, 2013) on the partnership between Arizona State and adaptive learning company Knewton (who is currently a partner with OpenStax). According to the story, ASU saw an 18 percent increase in pass rates and a 47 percent decrease in withdrawals from the math courses that used Knewton’s adaptive tools. At the same time, the collaboration raised troubling questions about who owned all the data collected from students' use of the software—and what they might ultimately do with it. Knewton's founder and former CEO Jose Ferreira discussed his vision of a future in which students' educational records would not just comprise a transcript and some grades; it would be a "psychometric profile": a strategic blueprint of her brain, describing her relationship to every single concept in every Knewton-powered course she takes, along with insights on how she absorbs and retains different kinds of ideas. That sort of data could be of great interest to graduate school admissions committees and potential employers. It could also, in theory, erode the privacy that has traditionally surrounded young people's schoolwork.

Another issue is that the way personalized learning is interpreted by companies like Knewton, is simply as variations in pacing. In other words, 'personalized' learning is essentially a type of adaptive learning that uses computers to scaffold instruction based on the student's previous levels of understanding when engaging with educational content (OED, 2017). Students learn at their own pace and are allowed to move on to the next topic only when they are ready. While this, in theory, sounds like a positive thing, it is, in fact, a very limited (and limiting) interpretation of 'personalization.' How educational content is structured and delivered, and what skills and types of knowledge valued and assessed, is predetermined and unalterable (i.e., it has been set up for students before they encounter a given platform or program.) Thus, in the sense that students get a 'tailor-made' experience within a highly constrained environment, the educational experience remains very much 'closed. What's more, notions like 'tailored'. 'personalization' and 'student-centered' do not really get to the heart of student agency, i.e., they still demand that students be 'consumers' of content. And yet, going back to my earlier point, they also demand that students be 'producers' of data – data that they have very little control over and which they, typically, do not own.

Finally, several critics have recently pointed out how biases can find their way into data mining and decision-making algorithms (Garcia, 2016; Gillespie, 2014; Kirkpatrick, 2016; Noble, 2018; NPR, 2018). In the context of OER and the new types of platforms that house them, this could translate into stereotyping, putting up roadblocks and/or making assumptions about how students should be learning and – even – thinking. Thus, it seems incredibly important to consider the ideological implications of this shift toward 'personalized' learning. Open textbooks provide an opportunity to think not only about how we can make education more affordable, but what *kind* of an education we want to provide to our students, i.e., what systems of educational provision we want to become part of, and what types of educational processes and practices we want to encourage.

For institutions considering different options around open textbooks and OER, therefore, it is important to recognize that decisions around technology carry epistemological weight, and that different technologies not only enable and constrain different types of action, but also, in many ways, 'realize' different forms of education and schooling. Technological systems and artifacts have values and assumptions embedded into their design which can be at odds with the educational goals and practice of a specific school, department or community (Flanagan et al., 2008; Johnson, D. G. 1997; Introna & Nissenbaum, 2000). As Edwards (2015) has argued, "it is the ontologies, codes, algorithms and the linking of data, the applications of technical standards, and ways in which decision-making and reasoning are articulated in computer software that (along with the hardware and the electronic infrastructures of networks) make things […] perform in [certain] ways and become specific actors in particular educational practices." (p.271) Moreover, placing an 'open' artifact into a 'closed' system will have implications for how this artifact is used and the resulting perceptions of the artifact based on that usage (i.e., how that artifact is given meaning). It will, therefore, have a very real impact on how ‘openness’ is practiced and the benefits that ultimately has on teachers, learners and educational institutions.

4.6. Conclusion

In this chapter I have examined how different stakeholder groups interpret ‘open’ and how their interpretations are shaping the ways that open textbooks are currently implemented in Californian higher education. Drawing on the social shaping of technology perspective, I have provided an avenue for understanding what openness means in practice, and how it can be better understood and researched. In discussing open textbooks, I have illustrated many of SCOT's main tenets, e.g. the various social interactions that surround and influence technology design and implementation. Using SCOT, I have identified open textbook development and implementation as a multidirectional process.

In addition, I have argued that it is increasingly important to consider how ‘openness’ is being shaped by emerging educational initiatives and practices. The way in which these new practices, especially for- profit ventures, will generate revenue, their increasing public media presence and coverage will contribute to the way openness will be realized in practice and conceived of in the educational imaginary. While this creates the potential for new discourses to obscure or rewrite the history of openness, it also makes it possible for other dimensions of these initiatives to become invisible. For instance, who is involved in creating them and for what purposes will not necessarily be as visible as in the case of ‘old school’ open textbooks (i.e., PDFs published on departmental or personal websites).

Future research could look further into how local context and local needs can be integrated into the design of open textbook initiatives. For policymakers, a clearer and more diversified picture of desired values and impacts across settings is likely to make it easier to create policies that offer context-sensitive solutions. It might also be useful for future research to further investigate disciplinary differences in how openness is understood and practiced. In addition, since few instructors identified benefits to open textbooks beyond cost savings, it may be important to increase awareness about the other potential benefits of openness (e.g. collaborative approaches to teaching; increased pedagogical degrees of freedom). For this purpose, research investigating concrete pedagogical benefits of open textbooks and other OER in specific contexts (i.e., specific disciplines, courses and types of institutions) would be particularly beneficial. While savings for students is an easy sell, in the long run it might not be enough to sustain the momentum around open textbooks, particularly if these resources – like MOOCs – cease being 100% free.

Lastly, it is important to emphasize that, while SCOT underscores the importance of analyzing how different groups imagine a certain technology and its uses, the work does not end there. This chapter has focused on interpretations and narratives of ‘openness’ and how these are impacting the developmental processes of open textbooks. Ultimately, however, technology is both shaped by people and shapes the environment and practices of users. The relationship between technology and society, in other words, is always multidirectional. The next chapter will thus examine how the technical characteristics of open textbooks might constrain the ways that they can be interpreted, and in doing so how they might exert a shaping force on the institutions within which they are implemented.

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CHAPTER 5: MODULARITY REVISITED: FROM KNOWLEDGE BUILDING BLOCKS TO TURNKEY TEXTBOOKS

> The [print] textbook was the answer to the educational challenges of the 19th century, but it is the bottleneck of the 21st century. The textbook of today remains static, linear in organization, time-consuming to develop, soon out-of-date, and expensive. Moreover, a textbook provides only "off the rack" learning that doesn't cater to the background, interests, and goals of individual students. Communication and information technologies give us a golden opportunity to reinvent the textbook. (OpenStax, 2012)

5.1. Introduction

In the previous chapter, I described how different parties within the open textbook ecosystem—instructors, providers, advocates etc.—have differing interpretations of what they are doing, something that is enabled in large part by the fuzziness of 'openness' as a concept, as well as the nature of the open textbook ecosystem itself. I have also demonstrated that the ways in which people 'interpret' openness shapes how they ultimately 'do' open – i.e., how they design, implement and use open textbooks and related technologies. Moreover, by presenting a web of relevant 'social groups' (or, stakeholders) involved in open textbook development and use, and examining the tensions between those groups, my analysis has argued that open textbooks and the practices/ dynamics surrounding them are best understood systemically and relationally – that is, as embedded in socio-technical systems in which infrastructures, producers, users, regulators, and other intermediaries are themselves entangled, and in which a number of different interests, values, goals and expectations interact.

In this chapter, I extend this argument by focusing on a case study of OpenStax, an open textbook publisher based at Rice University in Houston, Texas. Specifically, I take a systems approach to analyze the movement of OpenStax content — from production and circulation to consumption — and its structuration through social and technical infrastructures to identify the points at which movement is constrained. By technical infrastructure, I mean the hardware, software, middle-ware and protocols that allow for the encoding and electronic exchange of information. By social infrastructure I mean the 'assemblage' of standards, practices, organized labor and values, which themselves involve a range of people, institutions, policies, and financial arrangements (Kitchin & Lauriault, 2014), and which support the creation, circulation and adaptation of open textbook content. By following the sociotechnical processes involved in the production, circulation, consumption and maintenance of OpenStax content, this analysis emphasizes the dynamic interplay between organizations, vendors, technologies and individuals involved in open textbook implementation; the tensions between different systems and sub-systems that create, 'absorb' and modify open textbook content; and the invisible labor of formatting, maintenance and repair that goes into 'doing' open textbooks.

The reason for selecting OpenStax for this study is threefold.[31] First, OpenStax is one of the oldest and longest lasting OER projects in the US and, arguably, one of the most popular (and best-funded). Second, because of its size, scale and reach, OpenStax illustrates the complexities of developing, distributing and, importantly, reusing/remixing open content in ways that smaller scale projects do not (e.g., problems around standardization and the frictions between systems). Finally, OpenStax's expansion beyond content-related resources (i.e., textbooks) to the delivery of technology solutions (i.e., adaptive courseware and learning analytics) reflects broader trends in educational technology and educational publishing, which

[31] I am aware that OpenStax represents one model of open textbook development and that many others exist, ranging from faculty writing and posting open textbooks (usually PDF versions) on their personal and/or departmental websites, to wiki-type crowd-sourced projects and student-authored textbook alternatives. Some of these models have been explored elsewhere (e.g., Hilton III & Wiley, 2011; Kidd et al., 2008; Spiro & Alexander, 2012; Sutton & Chadwell, 2014; Wiley et al., 2017). Others (e.g., FIT's Fashion History Timeline), I will be discussing in future work.

are bound to shape not only the future of open textbooks, but higher education provision in the US more broadly. Although this chapter is centered around OpenStax, my analysis does occasionally bring in other providers and projects, which are compared and contrasted with OpenStax. This allows me to draw a more complex and nuanced picture of the open textbook ecosystem and the issues surrounding open textbook implementation. It also allows me to make more generalized conclusions with regards to the evolutionary path of open textbooks.

I begin my discussion by summarizing briefly the history of OpenStax and its emergence out of the Rice-based Connexions project, which was created in the late1990s to promote collaborative development, free sharing, and rapid publishing of scholarly content on the Web. I describe how Connexions had to 'adjust' its original vision around plug-and-play content creation and use (and highly modularized content structures), to cater to a market that was mostly looking for 'readymade' learning materials (i.e., professional-grade textbooks). This goes that show that openness is not immune to market forces or competition. I then discuss how OpenStax content is currently created, managed, maintained and consumed. This involves mapping the different parts that make up OpenStax from a technical, business/ operational and market perspective; analyzing the nature of the relationships between these different parts and their affordances; and discussing how they relate to other components of the broader open textbook ecosystem (e.g. technology providers, print distributors, users, other open textbook providers). My analysis also focuses on making visible the specialized labor and skills that go into developing content that is open and – importantly – reusable across systems and applications (i.e., that is formatted properly) and which instructors often lack. This is an issue that very much affects the reuse and remix of open textbooks, yet is frequently overlooked in both the media and in scholarly conversations around open textbook implementation. Ultimately, this chapter sees

OpenStax as exemplifying a form of 'openness' that is less about the freedom and creativity of 'mixing and matching' resources and more about creating products that interoperate with those of other vendors within the digital education market.

The findings in this chapter are drawn from interviews with OpenStax leadership and staff; interviews with other OER providers; as well as newspaper and magazine articles, organizational reports, press releases and other online sources relevant to the issues discussed in this chapter.

5.2. From Connexions to OpenStax: The origin story

OpenStax is an extension of a program called Connexions (CNX), which was started in 1999 by Richard Baraniuk, then Assistant Professor (and now Victor E. Cameron Professor) of Electrical and Computer Engineering at Rice University. According to an early promotional document co-authored by Baraniuk (Henry et al., 2003), the project was motivated in large part by Baraniuk's frustration with the textbook he was using in his undergraduate course on Digital Signal Processing (DSP). Reportedly, Baraniuk was concerned that his students just weren't 'getting it.' While their knowledge reflected in the exams showed that they had absorbed what he had taught, he wasn't convinced that they understood how different concepts were related, or how they 'fit into the bigger picture.' Students' thinking was linear, unidirectional and tied to the structure and sequence of the textbook. Wanting to provide a better learning experience for his students, Baraniuk became focused on finding a way to present the information in a way that would show how the concepts in his course were connected to each other, as well as to concepts they studied in prerequisite courses and courses that would follow. He thought about writing his own textbook

– to replace the four that he was then using – but his Dean at the time suggested that he "do something clever with the web"[32] instead.

After brainstorming with one of his graduate students, Brent Hendricks, Baraniuk became interested in the possibilities of Free and Open Source Software, and put together a small team that began working on creating an open repository of user-generated content[33]. Ross Reedstrom, a biologist with expertise in databases who was then working at Rice, joined the team shortly thereafter. As Reedstrom, who is now Senior Developer at OpenStax, explained to me when we met, the idea was to build a platform that would house 'custom' digital course materials – that is, materials that would be adaptable to a wide range of learning styles, and that would encourage students to explore the 'links' among concepts, courses, and disciplines.

Ultimately, the team envisioned an interconnected educational environment where worldwide, cross-institution communities of authors, instructors, and students, would come together to collaborate on the creation of knowledge 'building blocks' (or, 'chunks') from which courses could be constructed. In this imagined environment, knowledge existed in a continuum and disciplinary divisions were arbitrary and porous. Rather than provide content straight-up (as OpenStax does today), the intent was to build a system that would enable instructors (and other interested parties) to create and contribute their own. Specifically, Connexions imagined instructors coming to the CNX platform (and, specifically, the site's 'Legacy Editor') to create small 'modules' (rather than entire textbooks) – i.e., standalone learning resources such as single

[32] Interview with Ross Reedstrom, March 2017

[33] For an extensive and insightful discussion on the influence of the Free and Open Source Software movements on Connexions, see Kelty's (2008) *Two Bits: The Cultural Significance of Free Software* (esp. Chapter 9).

chapters, lab exercises, classroom activities etc. – that other instructors could then ‘weave together’ to create more complex wholes.

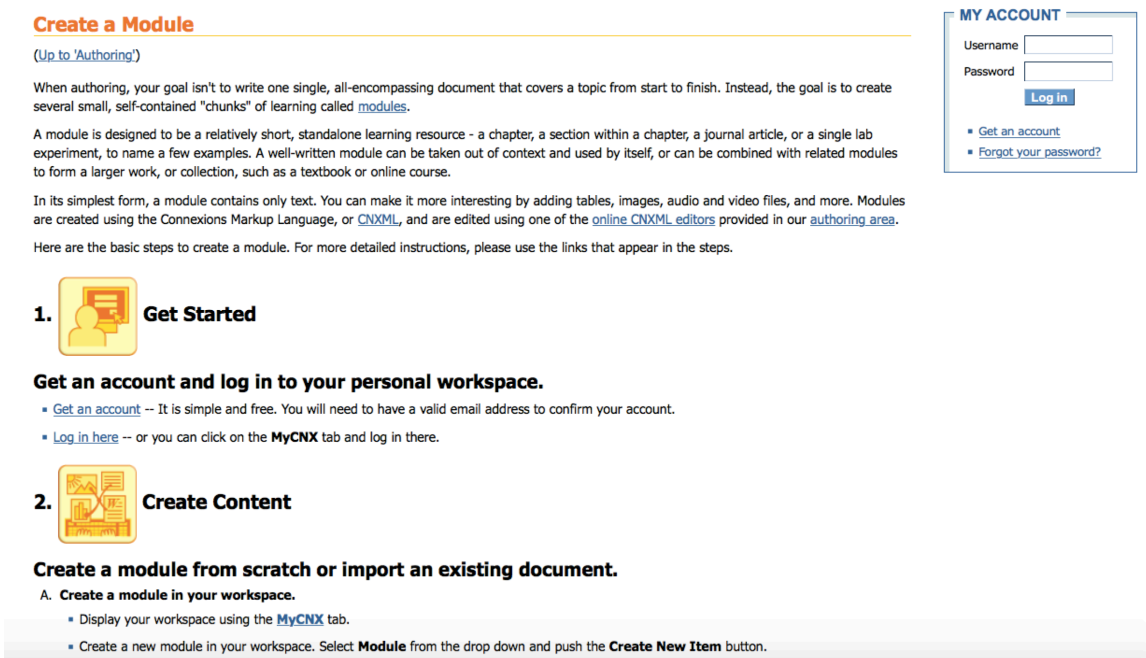

Figure 5.1. The CNX Legacy Editor

The following is an excerpt from a 2009 promotional document (‘Sharing Knowledge and Building Communities’) which describes the idea behind Connexions in more detail:

> A global community of authors continuously converts “raw knowledge” from the continuum into small, self-contained modules of information, the equivalent of a page or two in a textbook. Modules can be imagined as special Web pages with hyperlinks pointing to prerequisites, applications, and supplementary material. Modules are placed in a database repository (the Content Commons) to be used, reused, updated, and adapted. Instructors use a Collection Composer software tool to weave modules into customized collections that can be placed on the web, presented in class, or printed as a paper text. Students and other learners access web collections or the repository directly using special visualization and navigational tools designed to highlight the non-linear “connexions” among concepts both within the same course and across courses and disciplines. […] In Connexions, content is developed collaboratively by a community of authors under an open content license. All materials in the Content Commons are thus

freely available to worldwide communities of authors who can collaboratively create, expand, revise, and maintain them.

The success of the project rested on the premise that instructors would *want* to do this type of work, and that they would (from a technical standpoint) *be able* to with a fairly reasonable amount of effort. In short, it was expected that content (i.e., modules) would be created in two ways: authors would either write the content right into the CNX system, or they would import it. Either way, authors would have to mark up their document to make it machine-readable – that is, easily interpreted by computers.

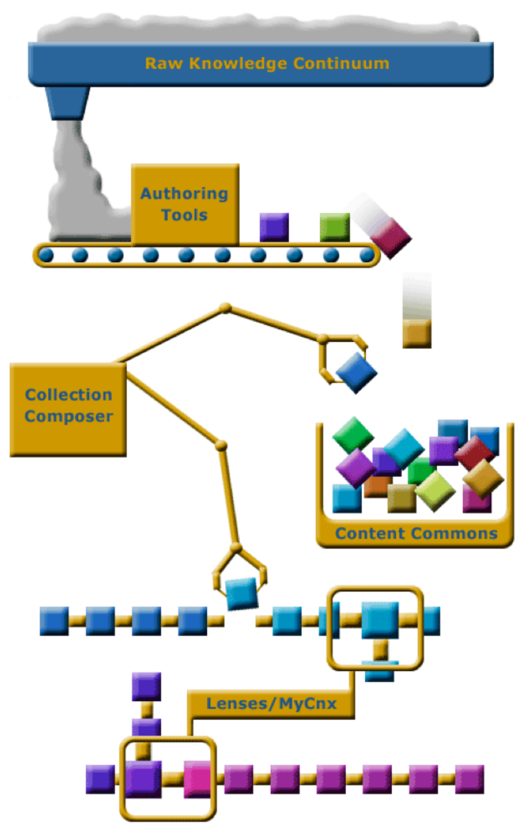

Figure 5.2 A representation of the authoring workflow in the Connexions system (CNX).

After much deliberation, the Connexions team had decided to use their own, custom markup language[34] called Connexions Markup Language, or CNXML. CNMXL is a specialized version of XML (eXtensible Markup Language) and it is the markup language that OpenStax uses to this day to create their textbooks. XML is popular in the publishing and documentation world, as well as in web services to transport data over the network. In separating content from presentation, XML compartmentalizes content by structurally describing each element on an electronic document and turning these into small modules of data that can be reused (Polsani, 2003). The compartmentalization of content makes existing content available on the web for machine consumption and enables the circulation of content through modular elements (Zisman, 2000). Modularization is a key aspect of modern software design that enables the management of complex systems by dividing them up into smaller modules and encouraging the reuse of these modules (Baldwin & Clark, 2000; McKelvey, 2011). XML also provides much better control over content than other languages (e.g., HTML), allowing authors to create a single document that can be used for web-based, PDF, or print delivery without having to worry about formatting or maintaining multiple files at once. However, there is a significant learning curve involved, especially for individuals who are unfamiliar with text markup. In addition to having to familiarize themselves with markup and the idiosyncrasies of CNXML, interested instructors also had to navigate a fairly complex interface and an imperfect 'importer' that was reportedly riddled with bugs, as Connexions lacked the resources to make it run smoothly and to keep it bug-free.[35]

[34] For a lengthier discussion on text markup, see Appendix III.

[35] To clarify, this is not a criticism of Connexions. These types of technologies are expensive and time-consuming to develop and there is no guarantee that the investment will pay off. To this day, the OER world lacks an efficient, flexible and user-friendly tool to build and customize OER resources, although projects such as Pressbooks and LibreTexts are working on filling this gap.

According to Reedstrom, the CNX system was hard to use for the average instructor (see also section 5.10.). And, while some instructors did, in fact, take the time to learn it and import their content, by the mid 2000s it had, according to Redstrom, become clear that Connexions "wasn't working well enough to turn it into an ongoing concern." Meanwhile, Daniel Williamson, a former undergraduate at Rice who had "caught fire" with the project, had started a small business with one of his classmates helping faculty import content into the CNX system. But that, according to Reedstrom, wasn't scalable either. "The fact that you actually required someone else to help you put the stuff in," Reedstrom stressed, "really just indicates how hard it was to mark-up content in a way that would work with our system." After the recession hit and funding for the project started drying up, Connexions went through a downsizing and made plans for how to shut down its operations. But then, Reedstrom added, "the idea started to get around about how expensive textbooks were" and, in 2012, OpenStax was created from the basis of the Connexions project.

OpenStax, however, took a markedly different approach to content creation and distribution. Instead of waiting for instructors to create and import content in the CNX system, the organization decided to create its own professional grade textbooks by hiring faculty to write these books from scratch, much like a traditional publisher would. To maximize return on investment, they decided to focus on introductory college courses with the highest student enrollment across the country. Why not use all the content that was already in the CNX system, I asked Reedstrom. He suggested that, while there was a fair amount of content (tens of thousands of pages in various disciplines, in fact), most of it was supplementary, fragmented or just too idiosyncratic:

> [I]t wasn't introductory texts, it tended to be more advanced, or in some unusual field. Like, we had some stuff on pig farming, a retired MDs notes on doing diagnostics with some pretty disturbing images of various stages of disease.. [What we geared for with OpenStax] was mostly just the idea of having a complete collection of content, sufficient to teach a whole class, as opposed to being supplementary materials or something very specialized for a specific domain. […] The original big goal was the 25 textbooks you'd need to get an Associate's degree.

According to OpenStax Editor-in-Chief David Harris, this strategy ultimately allowed the OpenStax project to scale. Harris, who has a background in academic publishing, joined Connexions in 2011, and played a key role in its rebranding as a textbook publisher. He thinks of the OpenStax publishing model as "OER 2.0." Whereas OER 1.0. was about content with high local value (funded by institutions or local governments, if at all) but infrequently adopted nationally, OER 2.0. is about OER intended to be used and adopted on a national level right from the start. While this requires a bigger investment up front, Harris noted, it pays off through wide geographic adoption. The working hypothesis for the launch of OpenStax was, thus, to professionally produce a "turnkey"[36] textbook by investing effort up front, with the expectation that this would lead to rapid growth through easy downstream adoptions by faculty and students. A 2017 Babson survey showed that OpenStax books are being adopted at the same rate as commercial textbooks in high-enrollment introductory undergraduate courses across the US (Seaman & Seaman, 2017). Meanwhile, according to a Rice news report (Ruth, 2019), OpenStax textbooks are in use at 48 % of colleges and universities in the U.S., and 2.2 million students used at least one of its books in the 2017-18 school year alone. As of February 2019, the college with most OpenStax adoptions was Pasadena City College, a community college in Southern California (with an estimated 46,396 students using OpenStax), followed by the University of

[36] Turnkey is a product or service that is designed, supplied, built, or installed fully complete and ready to operate. The term implies that the end user just has to turn a key and start using the product or service.

Georgia, a public research university based in Athens, Georgia, where an estimated 42,245 students use an OpenStax title.

5.3. OpenStax today

As of this writing, OpenStax (www.openstax.org) offers over 34 textbooks in subjects ranging from Algebra and Calculus to Economics, Sociology and U.S. History at the undergraduate and AP levels, but more titles are under development.

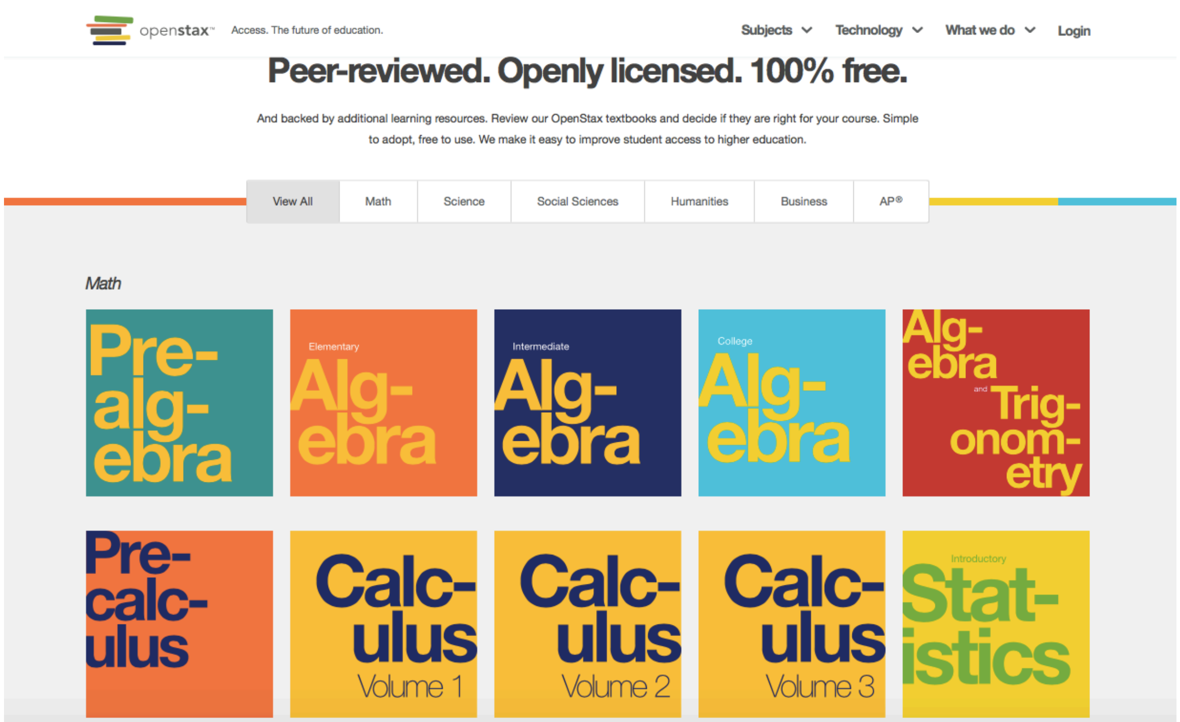

Figure 5.3. Some of OpenStax's math titles

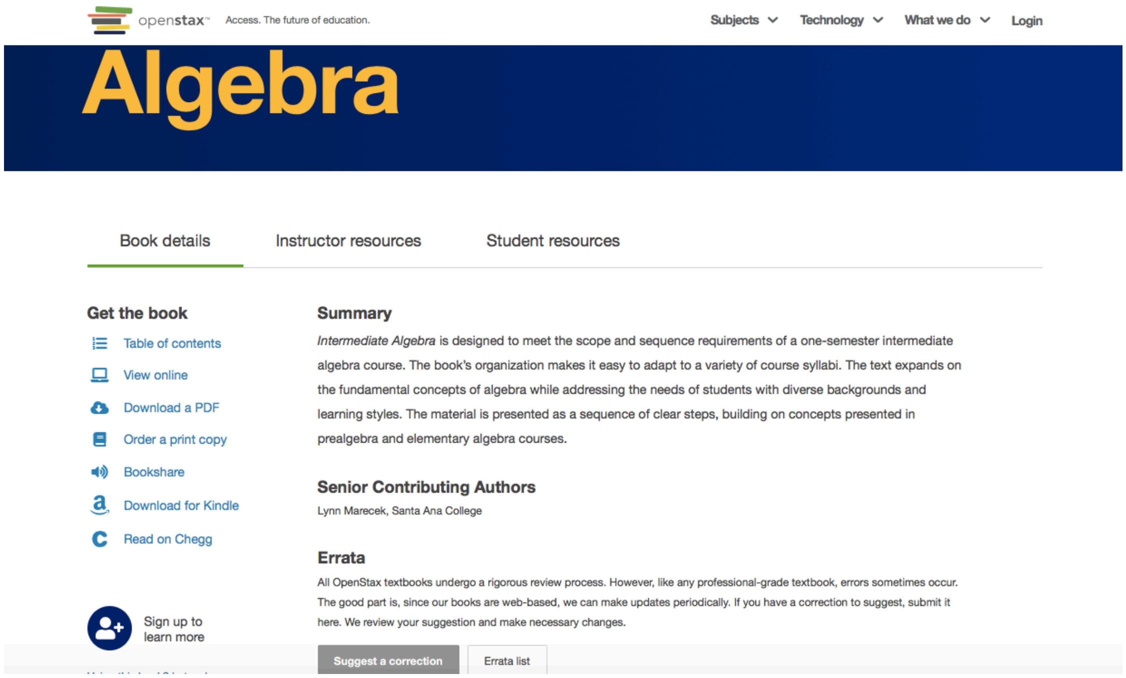

Figure 5.4. Example of an OpenStax Algebra textbook

The textbooks are licensed under a Creative Commons Attribution 4.0 License, except for the Calculus series of textbooks, which are licensed under the Creative Commons Attribution-Noncommercial-Share Alike license. All textbooks are available in web-view (HTML version with added graphics and multimedia), PDF (high- and low-resolution options), Kindle and in print (which can be ordered through Amazon.com or college bookstores). Some titles are available in additional formats, such as iBooks. While the PDF and web versions of OpenStax texts are free, proprietary formats like iBooks and Kindle are not. Print editions, meanwhile, cost anywhere between $25 - $65, depending on subject.

Ancillary materials, such as presentation slides, sample syllabi, test banks, and instructor solutions manuals, are available for some texts on the OpenStax website. Access to these materials are granted through an instructor login. In addition, OER Commons provides a hub that instructors can use to share resources they have created to use with OpenStax books and partner companies may provide additional, low-cost resources. These are listed on the Instructor Resources page for each book.

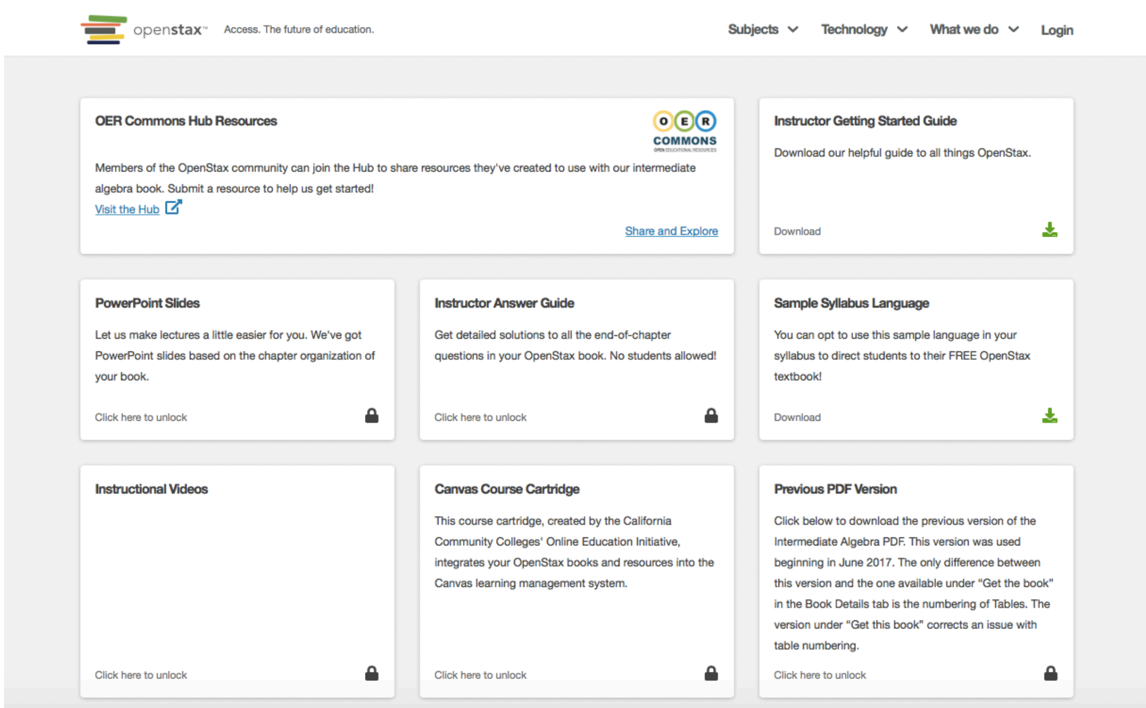

Figure 5.6. Example of OpenStax's 'Instructor Resources'

Meanwhile, the CNX website (www.cnx.org) also continues to exist, housing thousands of pages of user-generated content (modules, courses, assignments, textbooks etc.) alongside OpenStax's original titles, as well as user adaptations[37] of OpenStax textbooks. Renamed to "OpenStax CNX" it functions as a library for all sorts of OER materials, not just OpenStax textbooks.

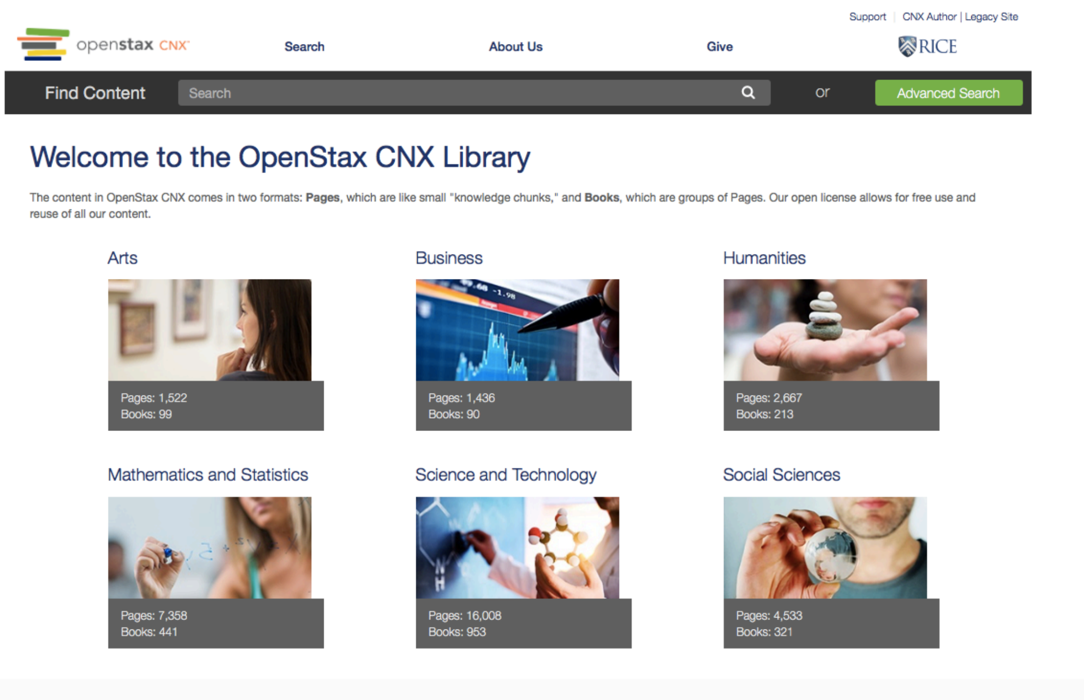

Figure 5.7. The CNX Library landing page

In addition, OpenStax maintains a Legacy CNX site (www.legacy.cnx.org), also referred to as "CNX Author," which feature's Connexion's authoring and editing tools. The interplay between the CNX and OpenStax websites can, in fact, be somewhat confusing. For example, when a user lands on the CNX website (www.cnx.org) it appears that the OpenStax textbooks are the only resources available on the site, as they are prominently featured on the home page. To access the

[37] To 'adapt' an educational resource means to change it with regard to one or more aspects to make it fit into a new context of use. Aspects are, for example, language, layout or terminology.

other content, a user has to click on the Search option from the toolbar, which then directs the user to the main CNX library. In addition, to access the CNX Author site, one has to click on a small menu tab on the top right corner of the CNX website.

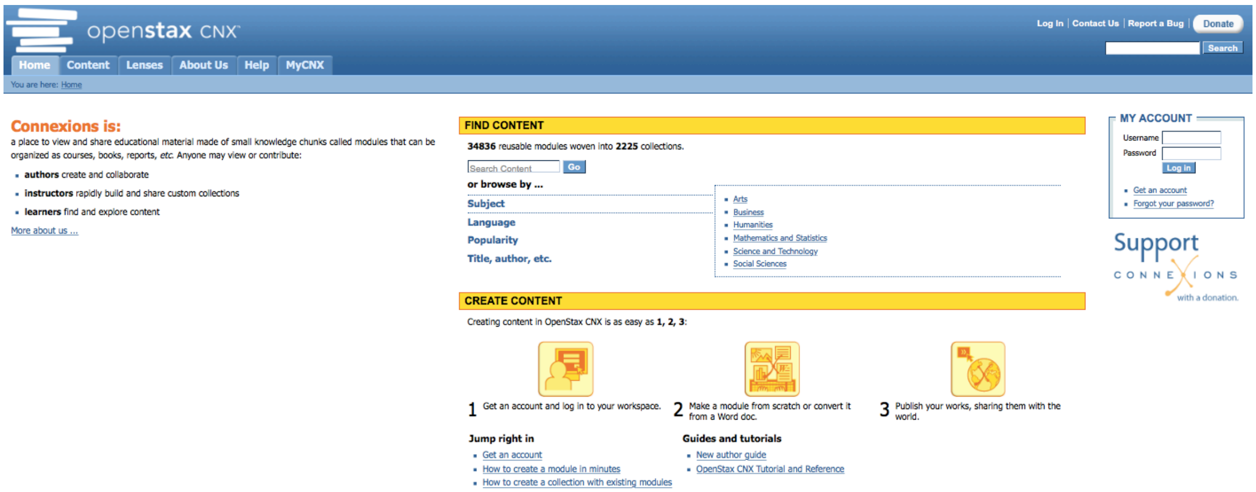

Figure 5.8. The CNX legacy landing page

The CNX library along with CNX Author constitute what in computing is often called a 'legacy system.' According to O'Byrne (1999), "a system exhibits legacy status if it is deficient in terms of its suitability to the business, its platform suitability or application software quality, with the effect that its asset value diminishes, as does its ease of operation, maintenance, migration or evolution." (O'Byrne, p.ii) IT companies have long grappled with the difficulties of managing – and oftentimes decommissioning – legacy systems (Seacord et al., 2003; Warren, 2012). As businesses and their products evolve, and as new software becomes available (or necessary), older systems become outdated or obsolete. However, the question of whether to maintain, redesign, or retire a legacy system does not have a straightforward answer. Replacing the old system without damaging or obliterating its contents, fitting the new system onto a modern infrastructure and/or isolating and preserving parts of the system that remain relevant to current operations are time-consuming and cost-intensive endeavors. In the case of OpenStax, the two Connexions websites still have an audience (albeit, presumably, rather small), yet their content and services are not that relevant to the organization's current mission and goals, as I discuss below. Thus, OpenStax has opted to keep the CNX sites independent from the OpenStax website and reduce their maintenance to almost zero.

5.4. From 'knowledge chunks' to 'turnkey' textbooks

OpenStax, in many ways, represents a 180 degree course shift from Connexions. Connexions argued that disciplinary constraints and divisions are arbitrary, and viewed knowledge as fluid, interconnected and continually under revision – i.e., as something 'living' and constantly changing (as opposed to something static and final). Moreover, modularity, which refers to the concept of making multiple modules first and then linking and combining them to form a complete system, was seen as a central driver of teaching innovation. Why the shift back to the 'linear' textbook, I asked the team.

Harris suggested that modularity continues to play a role in the work that OpenStax does, just not quite in the same way it did in Connexions. With CNX, Harris noted, the theory was that faculty will " adapt in order to adopt." What they learned, however, is that faculty are indeed more likely to first adopt a "readymade" text and then, potentially, adapt it: "[Faculty] will take and they will customize at the margin, so you need to provide them with an 85-95% solution, so they can adopt wholesale and then adapt it." Because some instructors will want to adapt, the content still needs to be tagged modularly. How many instructors did he think end up adapting OpenStax texts, I asked Harris:

> 5% will build and adapt. But if you give them a whole solution, probably 20% will make a custom version. But a custom version really is moving chapters around, it's not really changing the object. Maybe 5% is too generous.. let's say 5% of the market wants to go into [a repository such as] MERLOT[38] and build everything [from scratch.] It's such a small percentage that it doesn't show up in any market share analysis.

Here, Harris makes an important distinction between 'adapting' (i.e., making modifications to an existing text) and 'building' a text from the ground up by combining bits and pieces of content from all over the web. "There's only a very small minority of people who wants to go and take that module, take that 'Lego block,'", Harris argued, "combine it with another one and another one and create a whole different object". Research findings confirm Harris' suggestion as well. For instance, Duncan (2009) found that, in the entire collection of over 5,000 modules in the Connexions repository, only 15 had been used, translated, or modified more than five times. As well, Petrides et al. (2008) found that, while the Connexions collection grew substantially over the years, significant modification or revision of materials created by others happened rarely. "The truth of the matter", Harris continued, "is [that] it's too much work, [and] they don't have the time." Moreover, faculty are not rewarded for this type of work, he noted. Given how busy faculty are, and will continue to be for the foreseeable future, Harris said these numbers are unlikely to change:

[38] The Multimedia Educational Resource for Learning and Online Teaching (MERLOT) is a project of the California State University system. MERLOT is a repository of free online learning objects, including, open textbooks, online courses, tutorials, virtual labs, and reference materials covering a range of disciplines and learning objectives. Established in 1997, it is one of the oldest collections of OER. For more see: www.merlot.org

> People are going to talk about it, and they'll say "of course I want to be able to adapt and build, I wanna do all this," but when the reality meets the fantasy, and April goes into summer, and summer goes into fall, they don't have the time to do it, and they don't do it. It's not a desire issue. It's truly a workload issue and they don't have the time. And I don't see faculty time freeing up in any future that I can see.

Beyond unresolved issues around faculty labor, another problem that Connexions faced, according to Technical Director Kathi Fletcher, was that instructors don't write or share textbooks the way programmers do code. Indeed, "stringing together" educational content (as opposed to code) by combining multiple learning objects with really small granularity[39] is "very hard to do well and in a reasonable way". Modularity, she remarked, makes more sense for computer scientists – who are "very excited about small grain sizes and binding them together", because this is how computers work – than the average instructor in, say, Biology. Textbook authors typically don't start writing by thinking about "the tiniest object" that is part of what they are trying to compose, she notes – instead, they just "start writing, and that [writing] is flowing in some particular way." Moreover, textbooks tell stories and they tell them pretty effectively, Fletcher added – especially to new learners:

> We learn in a fairly linear way. We tell stories. Stories are much easier to remember than random collections of facts, because you have a narrative structure to hang that information on. […] Once you have a model in your head of physics, then new information is getting hung, again, it's getting hung on there, it's not just sitting in the soup of knowledge. Knowledge isn't a soup, it doesn't work that way.

[39] Granularity, which is the condition of existing in grains or granules, refers to the extent to which a material or system is composed of distinguishable pieces or grains. Granularity has implications both for the development and reusability of an open educational resource. Specific decisions related to granularity are governed by the organizational context in which OER are developed. It is a widespread hope that OER created in one organizational context (e.g., in OpenStax) will be routinely incorporated into different contexts. For a longer discussion of granularity in relation to OER see Wiley (2002).

Thus, according to Fletcher, creating textbooks with a clear structure and at least one pathway through the material "that somebody who understands it has thought through" is imperative for supporting students in introductory courses, who are novices by definition. What Fletcher seems to be suggesting here, and what textbook critics often forget, is that textbooks have an embedded pedagogy – that is, they tell students not only what material to learn but how to learn it as well (e.g., through examples, explanations, activities and exercises).[40] Some of the benefits that structured knowledge and curricular stability were also noted by the instructors I talked to – even those who were inherently critical of textbooks as a medium. Part of the reason textbooks (and textbook equivalents) remain so popular in undergraduate education, several instructors suggested, is that students "like them" – particularly learners who are less prepared for college, or otherwise struggling. Students that have difficultly analyzing and synthesizing different pieces of information, they suggested, find comfort in the idea of a 'main reference,' or a 'container' for everything they need to know to succeed in a course.

This goes to show that there is a certain durability to the ways we transmit, preserve, and acquire knowledge, which cannot be 'disrupted' by technology alone. Connexions sought to radically transform how people write, teach and learn; it sought to change conventions of scholarly work (Kelty, 2008) and conventions of pedagogy. Yet, historiographies of technology have time and again demonstrated that when technologies are adopted – like smart boards or laptops – they fit in with existing practices and norms, rather than 'disrupting' them (Edgerton,

[40] Several scholars have extended similar arguments over the years. See for example Brenni (2012), Sidaway & Hall (2018), Siegel (1978), Simon & Garcia-Belmar (2016) and Stinner (1995). Along these lines, Jim Butler, founder of adaptive learning platform, Fishtree, has argued: "Textbooks offer structured teaching and learning in a well-organized, aligned and unified manner. […] The paper form of a textbook probably will disappear, but the compendium of material in a textbook still holds great value" (Fishtree, 2014).

1999; Friesen, 2017; Nye, 2004; Surry, 1997). In fact, as Friesen (2017) shows in long durée[41] study of the textbook and the lecture (arguably, two of the most enduring 'technologies' of education), how we *do* education and schooling has changed remarkably little over the past 4000 years. MOOCs, Friesen argues, are still fundamentally lectures; they're just delivered over the internet. In addition, when change does occur, it is not because of sudden instructional or technological breakthroughs, but because of broader and more gradual cultural changes. Friesen's main point, is that this commitment we observe to the same, 'mundane' educational forms for millennia, is not so much a commitment to tradition or to fixed values, as it is to techniques, arrangements and practices that have been proven effective in the long run, despite their flaws and limitations. It is important to note here, that the 'durability' of the textbook form that Friesen describes does not pertain to the paper bound text, per se. Friesen acknowledges that textbooks are transforming, just as lectures are (see MOOCs). Rather, Friesen's point is that, even if textbooks transform into ' digital entities,' the content structure and modality more broadly will not go away.

5.5. Business model: An ecosystem[42] approach

[41] Longue Durée, or long term, is an approach to history writing pioneered by historians of the Annales school such as Fernand Braudel. It focusses on events that occur nearly imperceptibly over a long period of time, on slowly changing relationships between people and the world. For more, see for example Braudel (1958), Braudel & Wallerstein (2009), Olabarri (1995) and Redman & Kinzig (2003).

[42] An ecosystem is a term borrowed from environmental biology, where it is used to describe a system, or a group of interconnected elements, formed by the interaction of a community of organisms with their environment. Today, the term is used on a regular basis to describe the complex and inter-connected networks that comprise Silicon Valley and its counterparts: infrastructure makers, software engineers, systems integrators, search engine providers, and others. In the open textbook context that also includes students (as consumers), faculty members (as academic content creators and recommenders), publishers, distributors, librarians, and others.

Beyond pivoting on their initial ideas around authorship, publication and use-/reuse of educational content, OpenStax also made operational changes to ensure its long term sustainability. Connexions relied exclusively on institutional and philanthropic support (it's main backers included Hewlett Foundation, Gates Foundation, Michelson 20MM Foundation, Maxfield Foundation, Open Society Foundations, and Rice University). OpenStax continues to rely upon philanthropic funders to build new content (i.e., textbooks) and technology (i.e., Tutor), but it also generates revenue from print sales and collects 'mission-support' fees from an ever-evolving ecosystem of for-profit 'partners' (more on that below), which help support ongoing operations. In addition, OpenStax Tutor Beta also represents a new revenue stream -- $10 per student per course.

According to Harris, sustainability on the side of operations was a priority for OpenStax from the beginning. While he noted that he "can't see" a model where OpenStax doesn't rely on philanthropic support to launch new products (for reference, each OpenStax textbook costs between $500,000 and $2,000,000 to produce[43]), the goal has always been to become self-sustaining in terms of ongoing operating expenses. "You can't do what we're doing and not have plans to support the bills," Harris suggested. "However, part of our responsibility is to maintain that content and technology once it is produced. Content needs maintenance and technology needs maintenance." As well, philanthropists will occasionally lose interest or develop "donor fatigue", he added. Therefore, developing a model in which one can sustain the operation after they have produced the materials, is crucial.

[43] While there are other models of OER development with significantly lower production costs (e.g., crowdsourced models), these numbers provide insight on the costs attached to creating professional grade OER.

OpenStax's model for sustainability includes three types of partners: 1) distribution partners, 2) service providers and 3) institutional partners. Distribution partners are companies that redistribute the content that OpenStax produces, with OpenStax collecting a small fee in exchange. One such example is OpenStax's partnership with Apple, which sells some OpenStax titles in iBooks for $6.99 and returns 70% of that income to OpenStax. Service providers generally take OpenStax content and "enhance" it in some way – for example, by providing adaptive courseware, homework systems, flashcards etc. OpenStax has more than 50 partners in this category.

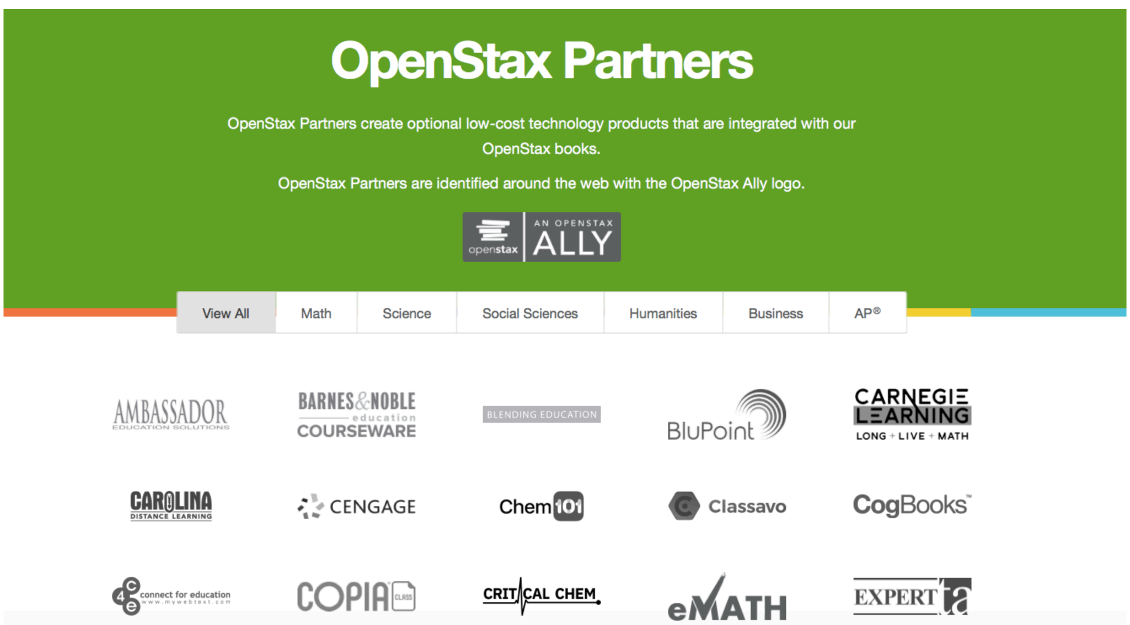

Figure 5.9. Some of OpenStax's for-profit partners

For example, WebAssign, an online homework and assessment tool, takes the OpenStax College Physics textbook and adds algorithmically generated physics problems, with problem-specific feedback, detailed solutions, and tutorial support. WebAssign resources are available to students for a fee of around $23 per course or lab. Another example is Odigia, who places OpenStax texts inside a platform with tools designed to measure and promote student engagement and collaboration. Odigia licenses its learning platform to institutions for $25 per course per student. Partners like Odigia and WebAssign give a percentage of the revenue they earn back to OpenStax, as “mission-support” fees – anywhere from 10 to 15% of what they sell. OpenStax has already published revisions of their titles, such as a second edition of their Introduction to Sociology, using these funds. In Harris’ view, this approach lets the market operate at peak efficiency:

> We believe in a market that is distributed, in which I’ll partner with company A if they can improve my offering and improve efficiencies. So that they might be better at courseware than I am in that market, but they’re not so efficient in content development. So by working together we can drive down costs and improve quality.

Meanwhile, OpenStax benefits not only by receiving mission-support fees but through free publicity and marketing. OpenStax doesn’t have a sales force, as Managing Director Daniel Williamson explained to me, thus relying on partners that showcase their materials for free:

> We don’t have a hundred parson sales rep army that goes and knocks doors, so we had to be very creative about how we did that. Because we also don’t have tons of money to spend wining and dining faculty, which is what frankly a lot of them are used to. So, instead we enabled this partnership ecosystem, which [essentially] gets us a marketing team. Many of these companies have sales forces and many of the times that they are going and trying to sell their product, at the same time they’re selling us.

Even if that company doesn’t make the sale, Williamson added, they have “still exposed that faculty member to OpenStax.” This was especially important in the early days, when OpenStax did not have brand recognition. But, the benefits also work the other way around, Williamson explained. When I asked him why companies partner up with them, instead of just taking their content off their website and using it without any financial commitment, he explained that these companies get access to "perks" as well, such as co-marketing opportunities. For example, OpenStax promotes their ecosystem of partners on their website, drive leads to them via forms on their website and do co-marketing at conferences. Importantly, their partners get "special benefits", such as textbook updates, which they receive before being "pushed out" to the general public – that, gives them an advantage in the market.

Finally, 'institutional partners' are the third type of partner that OpenStax works with. With support from the William and Flora Hewlett Foundation, OpenStax has created an Open Educational Resource Institutional Partnership Program to help cultivate open textbook initiatives on university campuses. Access to the program is based on an application process and is geared toward institutions that are already heavily invested in OER and ready to dedicate "the necessary time and resources" to scale adoption on their campus. OpenStax selects an annual cohort of 10-12 institutions from around the country and provides hands-on support and guidance around building systems, processes and practices that will promote and sustain OER use on campus. For instance, each partner receives individualized consulting on a strategic plan to increase use of OER, and up to 10 hours of tech support for using, editing, or adding to OpenStax books and custom content available on OpenStax CNX. While labor intensive and non-revenue bearing, these partnerships help drive awareness on campuses across the country not just for OpenStax but also other OER, which helps spread the word,' which in turn helps OpenStax gain traction in the market.

The source code[44] for OpenStax's software (incl. Tutor) is open-source and available on Github, a code hosting platform for version control and collaboration. Github allows OpenStax

[44] In computing, source code is any collection of code, possibly with comments, written using a human-readable programming language, usually as plain text. The idea behind Open Source is that by giving the source of a program away, people can learn from it, improve it, extend it and fix bugs.

developers to share their code freely with their partners and other members of the open textbook community, who can then re-purpose or 'fork' it, for projects of their own. By openly sharing source code with others, OpenStax makes their technical infrastructure visible and shared, while also relying on rely on the power of the wider community to help them audit and improve their code.

5.6. Making open textbooks

OpenStax uses two textbook development models. The first is an 'acquisition model,' where OpenStax purchases the rights from a publisher or author for an already published book and then extensively revises it. The OpenStax Principles of Microeconomics textbook, for instance, was developed this way. The second model is to develop a book from scratch–for instance, OpenStax Biology. Because the in-house team is relatively small, OpenStax uses vendors in two spheres to aid the development process. One is editorial, which includes identifying and hiring authors, writing the manuscript and ensuring that it's accurate, copy-editing and so on. The other is technical (what OpenStax calls 'production vendors') and includes experts working on design, formatting and markup. The process is similar for both models and is largely overseen by Editor-in-Chief David Harris and Director of Technical Project Management, Alana Lemay-Gibson.

On the editorial side, the developmental process starts with looking at the scope and sequence of existing textbooks and asking questions such as: What does the customer need? Where are students having challenges? Then, the editorial vendors will identify potential authors and put them through a rigorous evaluation—only one in ten authors make it through. A group of authors are then hired to develop a template for a chapter and collectively write the first draft (or revise it, in the acquisitions model). Generally speaking, OpenStax does not produce books with just a single author, due to the risk of the project taking longer than scheduled.[45] Several reviewers are hired as well (typically, at least three per chapter) to ensure that content aligns with the scope and requirements of the course. A second draft is generated, with artists producing illustrations and visuals to go along with the text. The book is then copyedited to ensure grammatical correctness and a singular voice. Finally, it goes through a final proofread and production. All the people involved in this process are paid. OpenStax does not rely on volunteers. Writers, reviewers, illustrators, and editors are all paid an up-front fee—OpenStax does not use a royalty model.

Editorial and technical production happen, to an extent, concurrently. Lemay-Gibson heads the technical production, which means managing all the technical pieces around taking a manuscript and turning it into an actual book. Before a manuscript can be transformed into a digital textbook, the raw text must be marked up using a special markup language. Markup languages work with a text editor, an editing program that shows the text, the source file, on the computer monitor with only one font, in one size and shape. Once a file is marked up, a program can be applied to it (referred to as a transformation engine) to output it in new formats. Common outputs include EPUB, PDF and HTML (for web-viewing), as well as device-dependent[46] formats such as iBooks and Kindle. Lemay-Gibson oversees this process along with the overall design of each text to ensure it is 'on-brand' and that it meets market needs for a given topic.

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[45] Many funders apply 'penalties' for each day that a project is late.

[46] Device-dependent refers to programs that can run only on a certain type of hardware (i.e., their ability to function depends on the devices on which they run). Device independent software components, on the other hand, are able to function on a wide variety of devices regardless of the local hardware on which the software is used.

As soon as development on a new textbook starts Lemay-Gibson's team puts together a questionnaire for the editorial vendor and the authors they are going to be working with to ask them questions about what design features this book needs to have – questions such as: What colors and font sets do you want to use? How's the layout going to look like in general? Where's the homework going to be? In addition, her team looks at market research to ensure that what goes into a book design-wise is driven by the market needs for that particular subject. A design template and a chapter prototype are then designed in-house (graphs etc. are contracted, and come in later) and shared with everyone involved in production. Lemay-Gibson admits that, because they single-source[47] and write everything in their own platform (i.e., the CNX platform), there are constraints on the design process, adding that " it takes a lot of testing and a lot of back and forth to make sure that we meet the needs of each market."

As noted earlier, OpenStax uses a custom version of the eXtensible Mark-up Language (XML) to produce their books, in particular a subset of tags that are appropriate to textbooks – what they call CNXML. These 'semantic' tags[48] refer only to the meaning of the text they enclose, not to the 'presentation' of what they enclose, and give the textbook document (or, collection of documents) the necessary structure to be 'exported' into a number of different formats, such as a PDF document for printing and a HTML page for web-view. The work of 'translating' the manuscript from a Word into the mark-up system used by OpenStax (CNXML) is done by XML production vendors (who in turn hire markup specialists from all over the

[47] Single-sourcing refers to the process of creating multiple deliverables from one set of files. Single-source publishing is a content management method which allows the same source content to be used across different forms of media and more than one time.

[48] See Appendix III.

world) and overseen by Lemay-Gibson's team. During this stage, the textbook documents are not public, but housed in a private server that the vendors are given access to.

The conversion to CNXML, like the writing of the manuscript, is done chapter by chapter. As soon as a full chapter is done, Lemay-Gibson's team will "start building a book making sure all the pieces of the book work like they're supposed to, so we don't have any surprises later." With so many individuals and teams involved in the production process, I ask her how consistency and quality are assured. Lemay-Gibson assures me that on the editorial side there's "all sorts of assessment that is done" on the books before they even accept a manuscript. Meanwhile, on the technical side, after XML conversion is complete for a chapter, and before her team accepts any work, they review the XML to "make sure it's formatted correctly, that everything's tagged properly, that there are no mistakes." Where they do often find a lot of problems, she notes, is with MathML. "People don't know how to write MathML, so we see all kinds of problems with how people attempt to craft that and we end up giving a lot of guidance." To support this process, they have developed over time "a pretty substantial" suite of documentation on how to do things correctly, because "so many vendors do it incorrectly." But still, on occasion the team is working with "such tricky MathML" that they've "tried to explain it in a 100 different ways" and the vendor "still can't quite figure it out." At this point, Lemay-Gibson notes, "it's easier to just jump in and do it." After the XML review is complete, content is migrated from the server where it's being developed to OpenStax's production server. Once it moves to production, OpenStax owns that content, which means that they are responsible for any subsequent changes or corrections to the markup. Once a document is properly marked up, a

CSS[49] stylesheet is linked to the XML document to style it – to transform it, in other words, into something that looks and feels like an OpenStax textbook.

5.7. Distributing open textbooks

Content is output in a number of formats and shared with OpenStax's end-users (e.g., students, instructors), as well as its partners, which include distribution (or, print) partners and service provides (i.e. ed-tech companies that take the textbook content and wrap value-added services around it). The format and mode of distribution differs between the two. Service providers are generally provided with an EPUB file of the content, which is essentially a zip file that compresses the HTML, CSS, and other content files (e.g., images) into one package. These providers typically do not use the online version of OpenStax texts (available via the OpenStax website) or the PDFs, as they are hard to edit and remix[50]. Instead, they 'ingest' the content from the EPUB and re-display it to end users via their own platforms. This usually involves some type of reformatting and restyling to make the content display properly in their system. According Technical Director Kathy Fletcher, because a lot of companies format and structure in HTML, exchanging content and making it work in different systems isn't as hard as it once was – that is, as long as the content is textual. Things get more complicated when scientific notation is involved. MathML, in particular, Fletcher noted, "is one of the bigger pain points." "Doing math

[49] Cascading Style Sheets (CSS) is a stylesheet language used to describe the presentation of a document written in HTML or XML (including XML dialects such as SVG, MathML or XHTML). CSS describes how elements should be rendered on screen, on paper, in speech, or on other media.

[50] Editing PDFs without a source file (or EPUB) is a time-consuming and imprecise process. The easiest changes to make are those that do not alter the pagination. More substantial changes that impact the page numbers require extracting the contents of the PDF into another file format. However, this will change the way the pages display. Moreover, extracting or 'exporting' content from PDF requires a paid version of Adobe Acrobat (Acrobat Reader can't extract text).

is hard, as Barbie says", she joked, referring to the well-known difficulty of rendering equations online.[51]

These are issues that students using OpenStax don't have to deal with. For students (and instructors looking to use the texts 'as is' – that is, without modifying them) the textbooks are made available in web view, in PDF, and in Kindle format, as well as in print. Some titles (e.g., Intermediate Algebra) are available in accessible format for students with disabilities through Bookshare. In addition, six titles are currently available in iBooks (e.g., Psychology, US History) for $6.99 and include extras such as videos, interactive graphics, demos, and assessments.

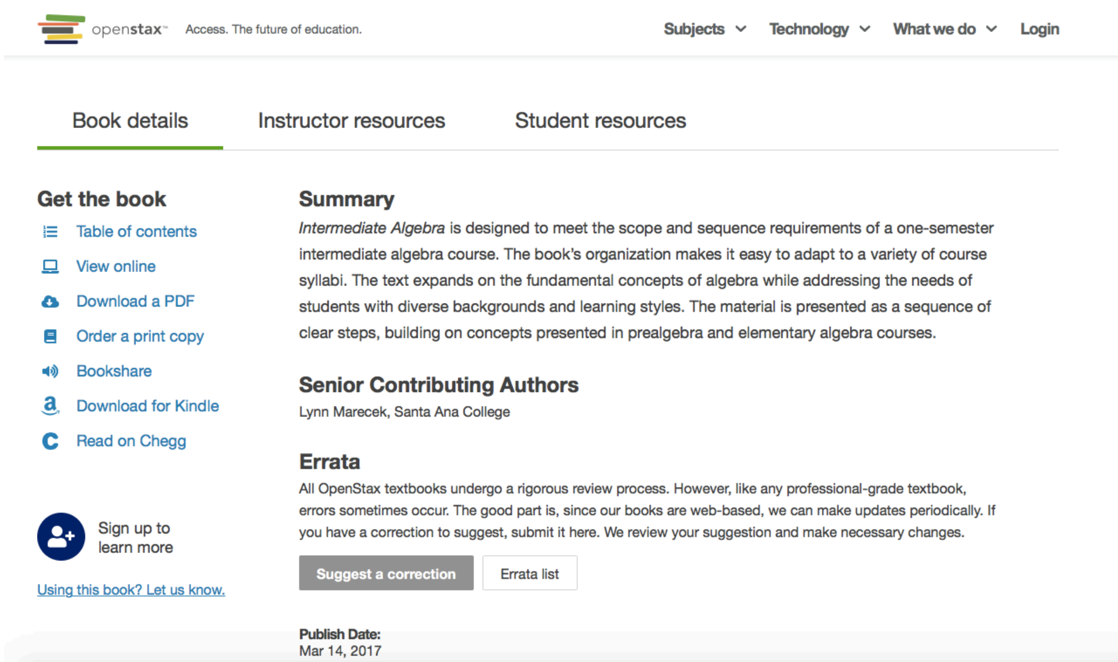

Figure 5.10. Format options for OpenStax's *Intermediate Algebra*

[51] See Appendix III.

Print copies can be ordered from a number of providers via the OpenStax website. Individual copies can be purchased through Amazon (for roughly between $30 - $70), while bulk orders can be placed through a number of providers that handle the fulfillment and distribution of OpenStax textbooks to college bookstore and K12 schools. Hard-cover, full-color versions can be ordered through indiCo (which recently bought up NACSCORP, the National Association of College Stores, Inc.), MBS and TriLiteral for an average of about $45 per textbook, depending on size. Soft cover, black and white versions can be ordered through XanEdu, LAD Custom Publishing and Montezuma Publishing, with prices ranging from $18 to roughly $40 per text.

According to Lemay-Gibson, while PDF remains their most widely used version, print sales for OpenStax remain “huge:”

> It’s funny, [e]verybody has been talking about the demise of the textbook longer than I’ve been here. It’s really interesting. It’s actually a growing thing for us. Our prints sales are huge, shockingly. Considering that our book is absolutely free online and that people have to pay to get a hard copy of the book, I’m amazed at how much we sell textbook-wise. […] It seems that there is a sub-set of students who want print, faculty order print form the bookstores, and our books are inexpensive comparatively for print. A typical biology textbook is $250-$300, and our maybe costs $49. So it’s a bargain by comparison [and] people buy them.

This is in line with findings from studies that have examined students’ preferences for print versus e-texts (Baron, 2015; Gregory, 2008; Dilevko & Gottlieb, 2002; Millar & Schrier, 2015), which note that the majority of students still prefer print. The usual explanation for these findings, is that students and publishers have not fully made the transition to digital and, in time, and as technology improves, this will change. It is worth pointing out, however, that OpenStax’s print sales have stayed the same over the years, even as their target audience has grown younger (and, presumably, more comfortable with digital technology). The role of print in the open textbook movement, along with students' interactions with both print and digital, are discussed in more detail in Chapter 6.

5.8. Maintenance and 'repair'

One of the big selling points of open textbooks is that they can be updated more frequently than print textbooks. Someone finds a mistake and goes online and fixes it, or a new theory is developed and the textbook can be updated 'immediately' – or, so the theory goes. In practice, however, this isn't always ideal. OpenStax found this out the hard way. According to Lemay-Gibson:

> When we initially started, we would make error corrections constantly on the web. And we used to update our PDFs every time we made a batch of error corrections [errata updates]. And then we found out that faculty were losing their minds over this, because we'd post an updated PDF, they're in the middle of the semester, and they've built their Syllabus on the existing PDF and we threw off the page count and they're ready to kill us.

To avoid confusion and frustration, OpenStax decided that they would continue to update the web-view as mistakes were reported and they got confirmation that they need to be corrected, but only update the PDF version of their textbooks once every year, in summer, in-between semesters. In addition, they decided that they would post a notice about it to keep instructors in the loop, as well keep the older version online, so that they could access it if desired. "We're not [traditional] publishers," Lemay-Gibson argued, "where we're constantly slapping 3rd edition, 4th edition. We roll out these updates and you can use the old book if you want, you can use the new one, it's up to you." It is important to note that all updates are made by the OpenStax team.

While there is a form to submit errors to OpenStax on their website, individuals cannot log into the site and alter the textbooks in any way.

Meanwhile, print files are also generated once a year. According to Lemay-Gibson, the publication cycle looks as follows: OpenStax starts errata corrections in January or February. They generate a new PDF but don't post it yet. Instead, they share it with their ecosystem partners, i.e., the companies that provide homework systems, test banks and complimentary material for the OpenStax texts. Early access to the updated versions of the textbooks is a perk of being an OpenStax partner. These companies then have plenty time to update all their materials. Then, around April, OpenStax sends the updated files to their printers and gets everything printed for the new year. And, in late June, all the PDFs that match the new stock are posted on the OpenStax website.

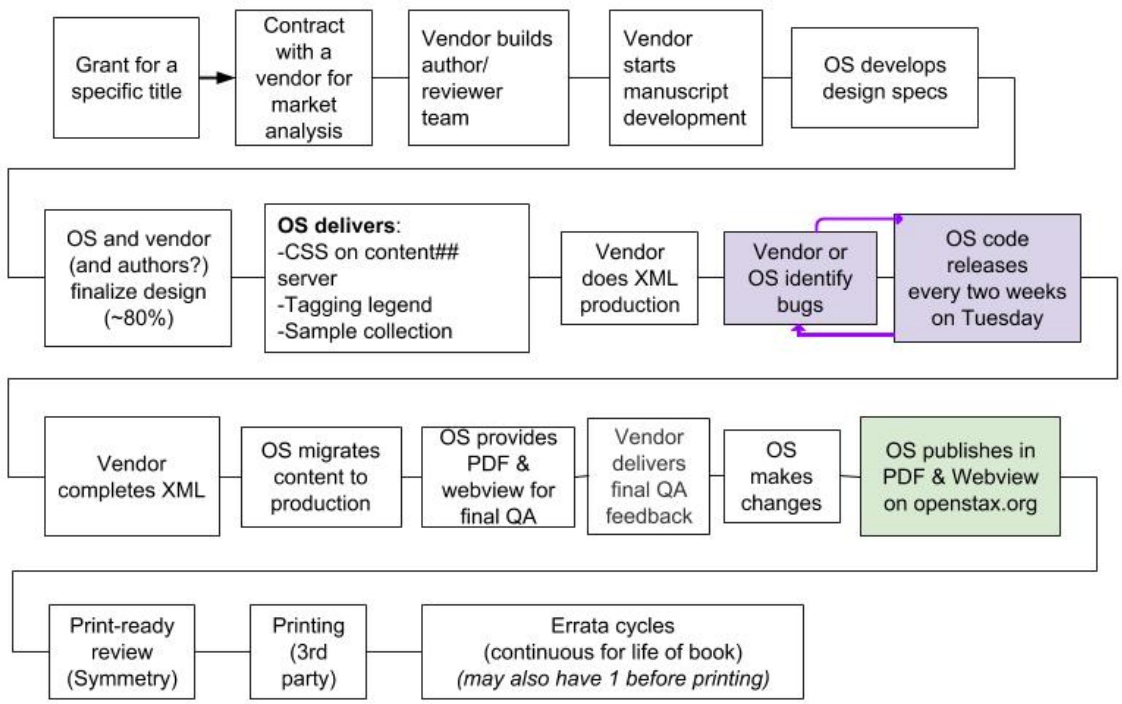

Figure 5.11. Diagram showing the OpenStax production workflow

To an extent, the OpenStax textbook (at least, the HTML version) is less stable than the traditional, printed textbook it is seeking to replace. But to what extent does the OpenStax workflow reflect a 'denaturalized' or 'destabilized' publishing process? Very little, it seems. As noted earlier, OpenStax corrects errors on their web-view continuously, which indeed disrupts the notion of a 'finished' text or document. Yet, the changes that are made to the HTML document are a lot more controlled (and limited) than in, say, a popular wiki page (where a 'final' text is impossible). While updates are made to the OpenStax web-view throughout the year, these are approved by the textbook authors and performed by the OpenStax team, rather than the public. In this workflow, the malleability and 'openness' of the textbook document are considerably reduced. Moreover, correcting typos or punctuation (i.e., errata corrections) is a different type of change in terms of scope and, possibly, impact than rewriting or deleting paragraphs, or adding in new sections. This level of change (i.e., adding, removing and/or rearranging a substantive amount of content) would only be implemented in an updated edition – much like in traditional textbook publishing. Lastly, as we saw, the PDF and print versions of the textbooks are – in contrast to the web-view – only updated once a year.

This is particularly interesting given the emphasis advocates place on the 'mutability' of open textbooks – i.e., their ability to be continuously updated and refined by legions of contributors. Beyond cost savings, this is one of the most frequently noted benefits of open textbooks and OER more broadly. Clearly, OpenStax texts *are* mutable and they are updated more frequently than traditional, bound textbooks. But, what OpenStax learned, was that more dynamic, fluid and 'open' wasn't necessarily better. Ultimately, user needs called for a more 'stable' or 'temporally final' object than the team initially envisioned. This gets us back to the point made earlier on (see section 5.4.), about the need for new technologies to align with – and compliment, rather than disrupt – existing teaching and learning practices. It also ties back to the discussion in Chapter 4, which highlights the ways in which openness is shaped and defined by social context.

5.9. Remixing open textbooks

Faculty who want to edit an OpenStax textbook can do so with the aforementioned CNX Legacy Editor, which generates output in HTML, CNXML, PDF and EPUB. As discussed, the Legacy Editor predates OpenStax and, according to technical director Kathi Fletcher, hasn't been fully updated in about 10 years. The reason, Fletcher suggested, is that effective editing tools are extremely expensive to develop and aren't used widely enough to warrant this type of investment.

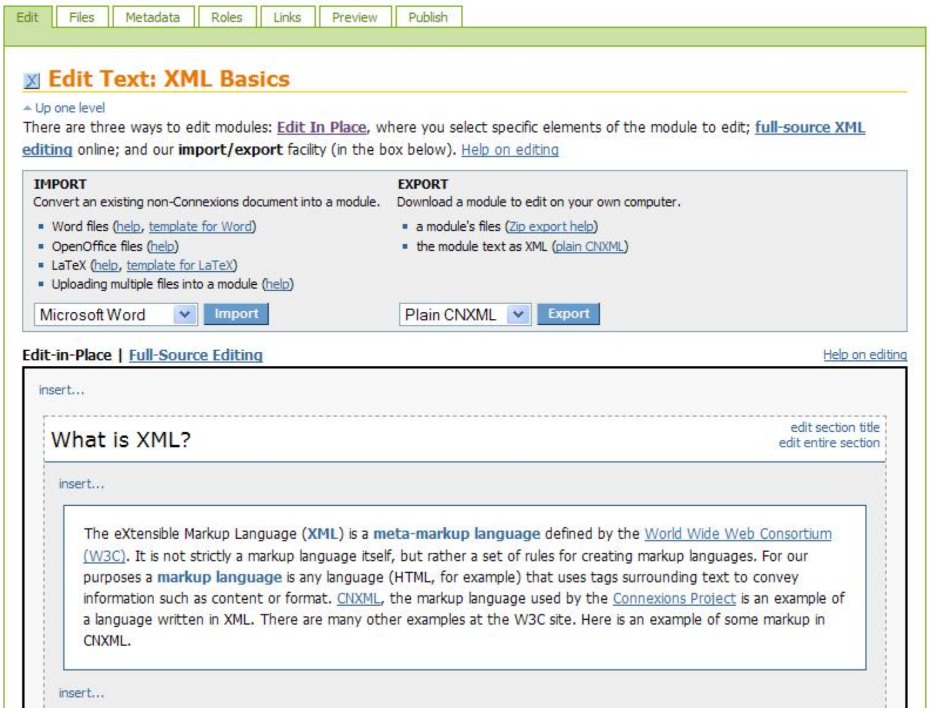

Figure 5.12. The Legacy Editor (Edit-in-place version) showing a paragraph within a section

Depending on the changes that somebody is trying to make, editing on the Legacy Editor can be "fairly easy and intuitive, or it can be next to impossible," said director of project management Alana Lemay-Gibson. A number of instructors I interviewed who had used it or attempted to use it, described it as "not great" and "not very smooth." Instructors also noted that the software is "full of bugs" (not surprising given the lack of updates), something that the OpenStax team was quick to admit as well. My general understanding, based on these conversations, is that the editor works best when working with native OpenStax content and when the changes made are not all that radical (i.e., rearranging or taking out sections or chapters). Things get significantly trickier when one is importing material, such as a module a faculty member has developed and wants to add to an existing text. If an import fails, “you’re kind of on your own,” Fletcher noted. In such a case, the instructor would then have to try and figure out what the importer didn’t understand, for which, she admitted, most instructors don’t have time.

The strength and weakness of the Legacy Editor is that it allows instructors to work right in the markup. This, gives them a lot of control over the changes they are making, but it also assumes that they are comfortable using OpenStax’s custom markup language, CNXML.

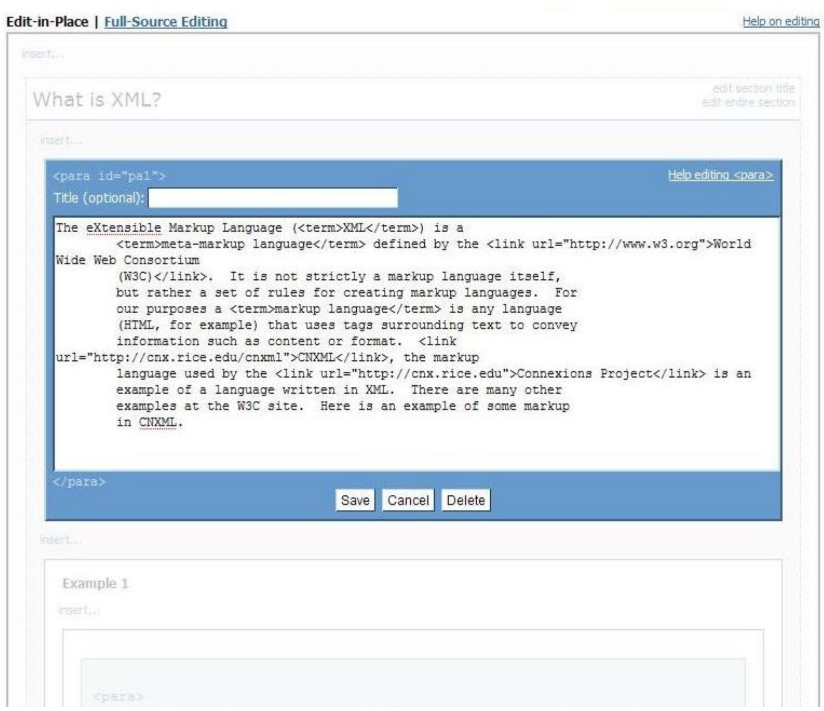

Figure 5.13. Editing an existing paragraph using Edit-in-Place.

And, while, OpenStax offers a number of guides and tutorial on how to write and work with CNXML via the OpenStax CNX website (cnx.org), these do not include information on how the styling and tagging differs between different titles. According to Lemay-Gibson, all of their books have unique tagging, which can make mixing content from different OpenStax books rather complicated. While it is technically possible to combine, say, their Psychology and Microbiology books, aesthetically the result would look choppy. In essence, one cannot mix and match two (or more) books that use different tagging, unless one picks one style and then retags the rest:

> If you're trying to mix it and style it, you can't if the titles are different, because each title has its own tagging. So if you try to have Psychology tagging ad microbiology tagging when you're generating the PDF, it will blow-up, it won't work. But if you want a semi-formatted PDF that's basically just text, yes you can do that. However, if you want to take Psychology content and [put it to the Microbiology book and use Microbiology tagging, that will work beautifully. But you'd have to retag all of it and it's a lot of work. You'd have to touch all of the markup.

Lemay-Gibson admitted that their markup scheme was developed in an ad-hoc way and is, thus, often more granular than it needs to be. If they were to "do it all again," they would use standard tagging across their texts and only tag differently what is different from title to title, she explained:

> [O]ne of the things I've learned is that, ok, these 30 things are generally the same across all of our titles. However, these other things are different. So, for example, there are different features boxes in Biology than in Psychology. But the bulk of the materials could be tagged exactly the same. And sometimes we got more granular unnecessarily, but we didn't know that until we had 15 books.

However, she added that going back and retrofitting it is time and cost prohibitive, as they have too many titles already. But, going forward they are trying to be a lot more standardized in terms of how they tag content in order to make their books more remixable. As well, books in the same discipline tend to use the same template, she noted. The series in economics, for instance, which includes Principles of Economics, Macroeconomics, and Microeconomics share some of their content and use the same tagging, which makes them a lot easier to mix.

Mixing OpenStax content with outside material is also challenging. It just "never look[s] and feel[s] as good as an OpenStax book", Lemay-Gibson said. To achieve a result that is aesthetically pleasing, all content would need to me marked-up from scratch, which is "tons of work" and requires expertise that most faculty don't have. In addition to the technical and design challenges is the issue of licensing. Nearly all OpenStax content has a CC BY license (the three-volume Calculus texts, which have a CC BY-NC-SA license, are the exception). If one wants to change or add an image or text section, for instance, they need to ensure that they're openly licensed or in the public domain and correctly attributed. That is, if they want to create a resource that is 'open.' Even the use of a single copyrighted image within a textbook that is otherwise CC BY licensed will affect the 'shareability' of the textbook outside the content of a given course (i.e., outside the course LMS).

OpenStax offers up to 10 hours of technical assistance annually to schools with an institutional partnership (see section 5.6.) who are looking to customize OpenStax texts. That support includes general guidance, styling and tagging information. As a non-profit, however, OpenStax doesn't have the resources to provide this type of service to every faculty member that is trying to adapt their books. To address this gap, publishing and technology companies within the open textbook ecosystem have started offering editing and customization services to instructors looking to modify OpenStax texts or create new resources or courses from scratch. For example, educational software provider Lyryx, who is a partner to OpenStax, provides editorial services to adapt the content and provide custom editions for a given course. The content of these adaptations can be from Lyryx open textbooks, open content available elsewhere, or from course notes developed by faculty. Among other things, Lyryx offers to develop new content; reorder content “where possible” and remove content not covered; format and proofread all material; and adapt material to be offered in PDF, print, HTML, and EPUB formats. Similarly, another OpenStax partner, publisher Montezuma, offers to design and print open textbooks for faculty, including modified OpenStax editions:

> Are you using OER or curious about doing so? Montezuma Publishing can help in a big way. We can access the material for you and help organize it to perfectly fit your needs. Simply provide a link to materials selected. Let us know which chapters/pages you wish to use and in what order. We will create a FREE PDF design per your specification that you can upload to Blackboard. (www.montezuma.com)

At the same time, OpenStax is cautioning faculty against creating custom print versions of their books, particularly where changes only include cutting or reordering chapters–which tend to be the most common types of modifications that faculty make. On their website, OpenStax notes that custom printing an OpenStax book can result in higher costs for students, even when custom books have fewer pages. This is because small or custom print runs are usually more expensive than large-volume print runs. Customization, of course, also limit resale value for students, which might or might not be a concern depending on the price tag on the customized edition.

Other content and technology providers in the OER space have also been working on editing and customization services. For example, the BCcampus Open Textbook Project, which is based out of Simon Fraser University in Canada, has imported several OpenStax titles into a book production and editing software called Pressbooks –with the exception of titles that include a lot of mathematical notation. Because Pressbooks uses LaTex/Mathematics (MathTex), while OpenStax uses MathML, straight-out ‘dumping’ OpenStax content into Pressbooks doesn’t work. According to OpenStax technical director Kathi Fletcher, “somebody has to sit down and take the time to actually [do the conversion between formats] and do it in a way that processes the book, creates a new version, imports that book into Pressbooks." Thus, BCcampus has so far focused on titles such as OpenStax Sociology and Psychology, that are easier to convert. These titles still require "a bit of fussing around", Fletcher notes, because of differences, for instance, in how OpenStax and Pressbooks format headings or style the table of contents. In addition to BCcampus, Lumen Learning is also using Pressbooks as an editing interface. Lumen is a for-profit company that offers technology tools and services to help institutions implement OER (incl. OpenStax texts) founded by open education researcher and advocate David Wiley.

A common textbook format would improve the interoperability and remixability of content offered by different providers, as standardizing content on a common format is essential for the smooth exchange of information between systems. Fletcher suggested that "there is interest" in the OER community, but developing a standard would require either philanthropic or government investment geared specifically toward the development, testing and maintenance of interoperability. Based on current and previous funding trends, which have largely focused on content development, this seems unlikely. Rather, the trend seems to be for various providers and community groups to 'harvest' existing content (including OpenStax titles) and to 'migrate' it into their own platforms.

Beyond Pressbooks and BCcampus, LibreTexts (an open textbook project based out of UC Davis) is another prime example of that trend. For several years, LibreTexts has employed student workers (primarily undergraduates) to transfer content into the LibreTexts platform and style it accordingly. In the beginning, students were trained to collect and integrate small 'chunks' of content from different websites. As the project grew, they started taking larger libraries of content and integrating them into their site, including content from OpenStax and the

CNX library. In fall 2018, the LibreTexts project received a $5 million pilot grant from the US Department of Education to continue this work, in addition to developing new content for STEM and career technical education courses.[52] It is important to note that there is no way to fully automate this collection and migration of content; it still requires manual labor to take content, format it and display it in the LibreTexts (or any other) platform. An OpenStax textbook that is 'absorbed' into the LibreTexts platform will no longer look like OpenStax content. Instead, it will be markup up to match the formatting and styling of the LibreTexts 'brand.'

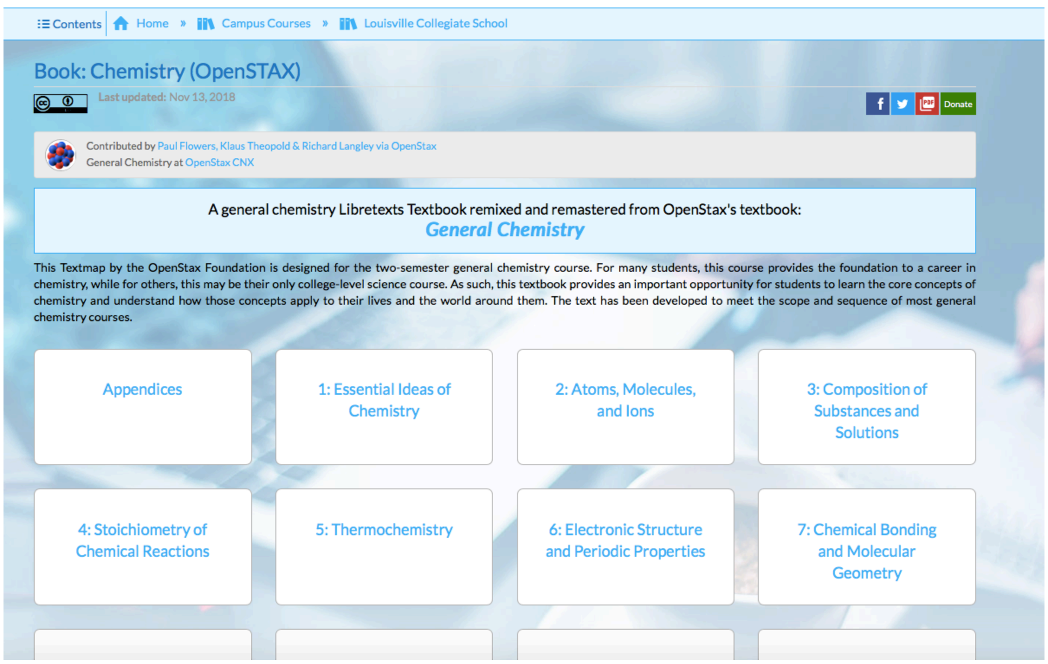

Figure 5.14. What a remixed OpenStax Chemistry textbook looks like inside the LibreTexts system (1)

[52] The grant will also support the creation of a zero-textbook-cost option for the American Chemical Society-approved curriculum for a bachelor's degree in chemistry. As of spring 2019, this grant is the federal government's largest single investment in OER. Read more about it here: https://www.ed.gov/news/press-releases/us-department-education-awards-49-million-grant-university-california-davis-develop-free-open-textbooks-program

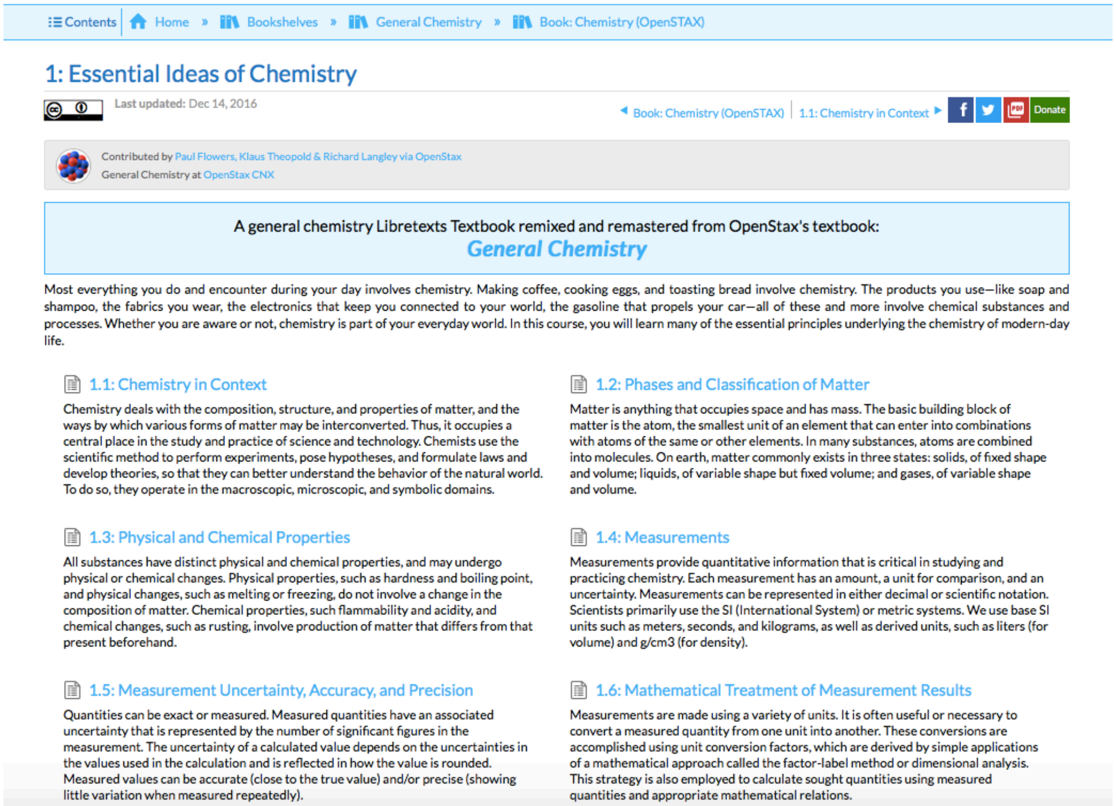

Figure 5.15. What a remixed OpenStax Chemistry textbook looks like inside the LibreTexts system (2)

Ultimately LibreTexts is trying to provide more than an editing environment. The project founder and director, Delmar Larsen, envisions the platform functioning as the 'go-to' place for instructors looking to construct, customize and disseminate open textbooks and other OER. According to Larsen, there are too many small projects "trying to reproduce the wheel" that lack the expertise and infrastructure to create real impact:

> There are a lot of campuses in California, that want to do an OER project. But the cost in order to start it up and make it work is pretty big. First of all, they don't know what they're doing and they need a lot of money. So what I can do for them, is, I'll do everything. We'll curate [the content], we'll keep it up, we basically say "come, you can build anything you want in our system and make it so that everyone can benefit from what you're doing." And that, I think, is very lucrative. So when UCLA throws in $10,000 to create an OER initiative it might not be enough to effect change, but if you

use that $10,000 in order for students to build something with faculty using our system, you can get a lot done with that.

Essentially, Larsen argues, there are "too many people making too many projects." In his view, these need to be integrated into larger projects such as LibreTexts.

Figure 5.16. The LibreTexts landing page

When I talked to Larsen, I wanted to know how much support faculty needed to customize textbooks in their platform, which uses the CKEditor, a WYSIWYG type text editor that enables writing content directly inside of web pages or online applications. Larsen recognized that it takes effort, both on the side of faculty, who have to become accustomed with applications and tools they might not be well-versed in, but also on the side of the team that provides the infrastructure for these services, be it OpenStax or LibreTexts:

> It's a serious problem, I think for a lot of these things […], but the thing is that we tend to bend over backwards to facilitate adoption, so we will help and go hand-in-hand with people in order to move things forward because we care about that. The reason we do so, is not necessarily the importance of one specific campus adopting, but if you build [a

> textbook] for one campus [according to] a specific design that they want, chances is that another campus will be interested in that similar design as well. We're doing the long-game in terms of facilitating adoption, really.

In the future, LibreTexts aims to add more advanced functionalities to the site, such as interactive 3D visualizations, embedded executable source code and the ability to include personal and class wide annotations. This desire (or foresight) to 'wrap' digital tools and services around textbook content reflects a broader shift within the textbook industry away from content creation and toward software provision (e.g., learning analytics, adaptive courseware). In the last few years, most textbook publishing companies have launched digital platforms; in fact, several have transformed their core identities from traditional textbook publishers to 'learning science' companies or 'digital education' companies (Oremus, 2015; Russell, 2017). OpenStax has followed suit by launching, in the summer of 2017, OpenStax Tutor, an 'affordable' adaptive learning system ($10 per student per course) that is companion to OpenStax online textbooks (discussed in more depth in Chapter 7). Tutor is currently in Beta stage and is available for the College Physics, Biology, and Introduction to Sociology 2e titles. In fall 2019, OpenStax will be launching its affordable online math homework system, Rover.[53] Rover will be available for their Algebra and Trigonometry, Precalculus, and College Algebra books for $22 per course per student and purports to offer an advanced problem-evaluation technology that "dynamically evaluates each step the student enters to see if it lies on a mathematically valid path to the solution, then gives hints and feedback specific to the student's approach." How does the pivot toward software and services that aren't completely free fit within a mission to 'open up' education, I asked the OpenStax team when we met. Editor-in-chief David Harris implied that

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[53] See: https://openstax.org/rover-by-openstax

the shift was tactical, suggesting that “pure textbooks will not be enough in the future; you gotta have technology around the textbook,” in one form or another. Managining Director Daniel Williamson, meanwhile, argued that, ultimately, openness wasn’t about a product, or even about being 100% free, all of the time. Ultimately, he suggested openness was about “giving students choices,” both in terms of how they learn, and in terms of how much they pay.

As a final note, it is quite interesting to observe how much OpenStax’s current services model resembles that of other, for-profit providers. Certainly, OpenStax’s textbooks continue to be available for free in PDF and web-view and both Tutor and Rover come at a much lower price point than similar products by Pearson, Cengage etc. In addition, their software is open-source and freely available on GitHub for scrutiny and extension. But, in terms of the scholarly and pedagogical assumptions that OpenStax products encode, both their textbooks and their software tools are closely aligned with established norms and standards. As discussed throughout this chapter, OpenStax has increasingly shifted away from open ideals such as peer-production and remix in response to market needs and trends. LibreTexts, on the other hand, continues to root for a more collaborative approach to knowledge production.[54] During fieldwork, I was told on several occasions (and by a number of informants) that OpenStax textbooks cater to more “conservative” instructors who are “scared of change,” and that peer-sourced models, like the one that LibreTexts employs, represent the future. Based on what I have learned and observed, I am dubious of such divisions. While it is too early to tell where the developments discussed here will lead, it seems unlikely that bottom-up models will be able to (fully) cater to the needs of mass higher education. Rather, it appears that the OER market will increasingly be structured

[54] It is important to note that the more ‘traditional’ OER model of instructors writing textbooks and posting them (usually as PDFs) on their personal and institutional websites persists as well.

around “hybrid” models, partnerships between non- and for-profits, and value-added services that supplement existing resources.

5.10. Conclusion

In this chapter, I have described the evolution of OpenStax from an experiment in crowd-sourced knowledge production, to a textbook publisher, to a learning software company. I have discussed how the company’s view on openness, modularity and authorship has shifted and adjusted to address both market needs and its own sustainability challenges. I have argued that open textbooks are rooted in their socio-technical production processes by describing the process through which a number of activities happen at OpenStax: making, distributing and maintaining OpenStax content. I have also discussed how their content is consumed both by users (students, faculty) and vendors. My discussion has highlighted the invisible labor of text formatting and markup, which is often overlooked in the OER literature, and which affects how and to what extent these resources are reused, remixed and redistributed. In particular, I have offered a counter-narrative to the common claim that digital content (be it by OpenStax or other provider) can be easily ‘mixed and matched’ to create new and coherent wholes. As my findings indicate, there are social as well as technical challenges surrounding reuse and remix in particular that remain unresolved (e.g., lack of format and formatting standards, lack of user-friendly editing tools, lack of instructor rewards) and that are stronger in some field (e.g., math) than others. Moreover, I have shown that there is substantial expertise and cost involved in building content with the hopes of having it reused, and even then it is not certain that this potential of re-use can or will be exploited in practice. Finally, my discussion of the CNXML markup language has illustrated a common argument in infrastructure studies and STS: that is, that infrastructures do not grow de novo, but instead “wrestle with the inertia of the installed base” (here, the Connexions software), and inherit strengths and limitations from that base (Star & Ruhleder, 1996, pp.113). In the next chapter, I shift gears slightly to discuss the interplay between paper and digital in the implementation and use of open textbooks. I return to the issue of adaptive software and personalized learning in Chapter 7.

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CHAPTER 6: OPEN TEXTBOOKS IN THE CLASSROOM: WHERE PAPER AND DIGITAL COLLIDES

> Once you've recognized that textbooks are just an assemblage of resources and that, in a digital world, there's no reason to bind it together and publish these en masse, then I think you can see a path to liberation from that industry model. You can disassemble, reassemble, unbundle, disrupt, destroy the textbook. It is truly an irrelevant format. (Watters, 2012)

> [P]rint is limited. Print does not have the flexibility and modularity necessary, especially if it's bound. And I think that there's an inherent sort of conservatism […] continuing to hold on to the model of a bound book. And I'm not sure how profitable that analogy remains. – Steven Zucker, SmartHistory

6.1. Introduction

In today's language, the print (text)book is a legacy technology to be phased out. Boundless Learning, an open textbook publisher that went out of business in 2015, declared in 2011: "[Print] textbooks are obsolete. […] They're boring, they're insanely expensive, and students deserve better.'' (White cited in Kirsner, 2011) Speaking to Steven Colbert in 2013, former Education Secretary Arne Duncan argued: "I think we need to move from print to digital absolutely as fast as we can. [E]ach year we spend $7 to $9 billion on textbooks and those textbooks are obsolete the day we buy them..." Duncan added: "We want to lighten those backpacks, we think those backpacks are far too heavy. And all that scarce money that we are spending on textbooks, put it into digital, put it into resources that students can use right now to learn." (Bedard, 2013). Along similar lines, Brian Kibby, the president of McGraw Hill, was quoted as saying at the Educause 2014 annual conference: "Textbooks are dead. They are dinosaurs" (Smith, 2014). And, Bill and Melinda Gates wrote in their 2019 letter: "The standalone textbook is becoming a thing of the past," twenty-five years after Bill Gates first predicted their demise in his book *The Road Ahead* (Gates, 1995). "Even the best text can't figure out which concepts you understand and which ones you need more help with," they added, noting how textbooks will ultimately be replaced by adaptive courseware providing students with a personalized, tailor-made learning experience.

In popular rhetoric, it is always either-or – digital 'versus' print, new 'versus' old. Current scholarship also tends to overemphasize the distinctions between digital and traditional print textbooks, presenting the digital as a rupture from previous incarnations of the book. Although the computational substrate that encodes the digital text creates new affordances, digital textbooks still heavily rely on past media conventions, genres, and norms, as well as the institutionally, culturally and historically constructed function of 'the textbook' (Drucker, 2006; Friesen, 2017; Ryan et al., 2014). Moreover, scholars in fields such as information studies, science and technology studies, media studies and the digital humanities (e.g., Edgerton, 2006; Edgerton, 2010; Liu, 2008; Murray, 2011; Sellen & Harper, 2003), have long argued that, far from rendering old technologies obsolete, the introduction of new technology often stimulates dynamic interactions between old and new media. As well, technologies often coexist, with 'legacy' technologies following new commercial pathways as new technologies are introduced. For example, fluorescent lighting did not replace incandescent bulbs; Cloud computing did not replace local servers; Netflix did not replace TV sets; and so on. In other words, although new technologies may change the function and uses of older technologies (i.e., 'reposition' them in the market), they rarely completely displace them.

This chapter examines the interplay between paper and digital in the implementation and use of open textbooks in order to challenge popular claims that open textbooks will liberate us from the 'mundane' and 'old-school' materiality of the printed text. Huhtamo (1997) has proposed that the aim of media archaeology, a branch of media history of which he is a leading figure, should be to study ‘recurring cyclical phenomena that (re)appear and disappear and reappear over and over again in media history, somehow seeming to transcend specific historical contexts’ (p. 222). Huhtamo called these recurring phenomena *topoi*, borrowing a term that goes back to the classical rhetorical tradition, where they referred to prefabricated formulae, which could be employed in the composition of orations. My examination of the myth of the death of the textbook and, more generally, of ‘paperlessness’ relies on a similar approach. I begin by examining more closely the so-called ‘death of the textbook’ – something which obviously has yet to happen, and which has in fact been announced more than once, starting in the early 20th century. I also examine the concept of the ‘paperless society’ and the notion that computers will eventually replace all traditional paper-based activities with electronic ones – and discuss how this idea has been applied to the education domain. I draw on my interview data to discuss attitudes toward print, and on classroom and conference observations to highlight the endurance of paper in the college classroom. I argue that the relationship between print and digital is a lot more fluid, dynamic and ‘symbiotic’ than technology pundits and ed-tech providers would have us believe, and indicative of a growing desire for multimedial and (truly) personalized learning experiences. In other words, I show that print and digital aren’t competing technologies; but complementary and, even, compatible. The practices I describe are layered, messy and still unfolding, as students and instructors adapt to the influx of digital content and devices in the classroom. Finally, my findings suggest that open textbooks tend to be used as ‘mere’ replacements for traditional texts, rather than as catalysts to introduce new pedagogies and assessment, which echoes previous researcg on the pedagogical uses and impact of open textbooks.

6.2. The death of (text)books… has been postponed

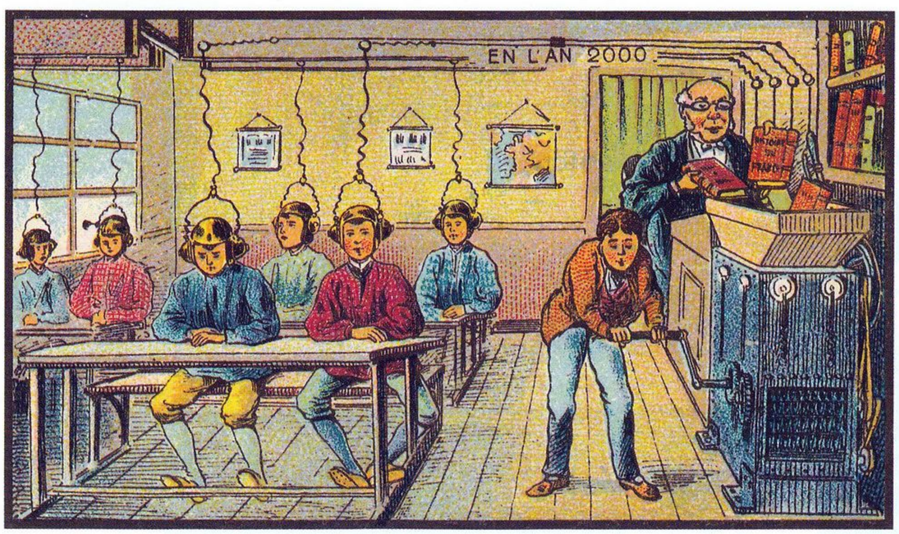
> In the real world nowadays, that is to say, in the world of video transmissions, cellular phones, fax machines, computer networks, and in particular out in the humming digitalized precincts of avant-garde computer hackers, cyberpunks and hyperspace freaks, you will often hear it said that the print medium is a doomed and outdated technology, a mere curiosity of bygone days destined soon to be consigned forever to those dusty unattended museums we now call libraries. – Robert Coover, The New York Times, 1992

Journalists, technology companies and science-fiction writers have been predicting the death of print and paper for decades (e.g., Bradbury, 1953; Coover, 1992; Huxley, 1998/1932; Lancaster, 1999; Price, 2012; Wells, 1899). H. G. Wells's 1899 dystopian sci-fi novel *When the Sleeper Wakes* takes place in the 22^{nd} century, where the protagonist searches for hardcover books only to find rows of "peculiar double cylinders" in racks inscribed with green lettering. In Alessandro Ludovico's *Post-Digital Print* (2016), the author points to a book by Octave Uzanne (illustrated by Albert Robida) published in 1894, titled *The End of Books*.

Figure 6.1. Literature and music at home. A woman listening to audio recordings of literature and music. A futuristic view on the subject of the end of books. Illustration by Albert Robida (1848-1926) in *La fin de livres (The End of Books)* (source: International League of Antiquarian Booksellers)

In the book, Uzanne suggested that the future of publishing would not be in the 'slow' and 'static' form of a printed page, but replaced by voice, available in a sort of 'on demand' platform transmitted through a gramophone. Uzanne's reasoning was that reading causes fatigue and apathy. Words heard through the tube, on the other hand, would convey energy, and thus the gramophone must inevitably supplant the printed page: "How happy we will be not to have to read any more; to be able finally to close our eyes". Uzanne predicted that, in the future, paper will be "abandoned," except perhaps for some limited use in business and private communications, since the printed word would no longer be satisfying compared to the new audio medium – and the thrilling experience of hearing the story actually being told.[55]

Similarly, the French artist Villemard created in 1910 a series of postcards showcasing his futuristic vision of life in Paris in the year 2000.



At School

Figure 6.2. This 1910 print is by the French artist Villemard and was part of a series "En l'an 2000" ("In the Year 2000") that was shown at the Exposition Universelle et Internationale, a world's fair held in Brussels. (source: Wikimedia)

[55] See also Silverman, W. Z. (2008).

In the postcard depicted above, we see the teacher feeding textbooks (L'Histoire de France) to a machine that appears to grind them up and deliver their content electronically into the heads of students. Here the concept of one technology – paper – being replaced by another – audio – is depicted even more explicitly. Interestingly, however, while the content is converted (into sounds rather than digital bits), the supremacy of the book as the primary repository of knowledge is in itself not challenged.

A few years later, in 1913, Thomas Edison predicted in an interview with the *New York Dramatic Mirror* that "books will soon be obsolete in schools." (Edison, 1913, cited in Sharples, 2019) In fact, Edison believed that one of the technological inventions he was involved with and invested in - the motion picture - would displace both textbooks and teachers alike: "Scholars will be instructed through the eye. It is possible to teach every branch of human knowledge with the motion picture. Our school system will be completely changed inside of ten years." (ibid). Edison invested a great deal of time and money in educational film ventures, which was matched by a substantial institutional infrastructure and bureaucracy to accompany the use of motion pictures in schools (Selwyn, 2016). In the late 1920s, Edison's vision remained unchanged: "In ten years textbooks as the principal medium of teaching will be as obsolete as the horse and carriage are now.... There is no limitation to the camera." (Edison, cited in Oppenheimer, 2004)

Increased efficiency was at the heart of Edison's techno futurism – much as it remains in tech and policy talk today. According to Edison, print textbooks were only "about two percent efficient" (Edison, 1922, cited in Cuban, 1986, p.9), whereas "through the medium of the motion picture […] it should be possible to obtain one hundred percent efficiency." (ibid.) While studies performed in the 1930s and 1940s on the educational use and impact of TV reported mixed results (e.g., Cook & Nemzek, 1939; Shayon, 1950), investments in classroom television continued and by 1971, public and private sources had spent an estimated $100 million on classroom TV (Oppenheimer, 2003).

Once radio broadcasting became mainstream in the 1920s and 1930s, interest in its application in educational context began to grow as well.[56] School boards, universities and commercial networks, like CBS and NBC, invested large sums into creating classroom broadcasts, or "textbooks of the air" (Cuban, 1986). Radio was going to transform stagnant classrooms and teaching practices that were "regimented, mechanical, and mindless." (Cuban, p.9).

The November 1924 issue of *Science and Invention* magazine promised that once radio finally entered the classroom, kids would love to do their homework (Novak, 2013).

[56] For a longer overview of the history of educational radio in the US, see for example: Bagley (1930), Haworth & Hopkins (2000), Niven (1961) and/or Purdy (1980).

Figure 6.3.: *Science and Invention*, November 1924 (source Paleofuture/ Gizmodo)

The magazine explained:

> With the everyday added perfections in the transmission and reception of radio, such a remark as the above will soon be a thing commonplace. Little Mary Jane will enjoy her radio lessons as much as she now enjoys her bedtime stories. Everything will be an "open book" to her. A complete set in the shape of a leatherette covered book will take the place of bulky primers and readers. Home work will now be a great joy to the kiddies and lesson will be learned with much greater facility.

However, by the early 1950s, interest in educational radio faded (Cuban, 1986) as mechanized visions of the future of education began to dominate the popular imagination. Intelligent machines, computerized learning materials – including, but not limited to textbooks – and robot teachers would increase the speed and efficiency of education by eliminating paper-based processes (perceived as slower and less efficient) and replacing them with automated ones (perceived as more dynamic and engaging).

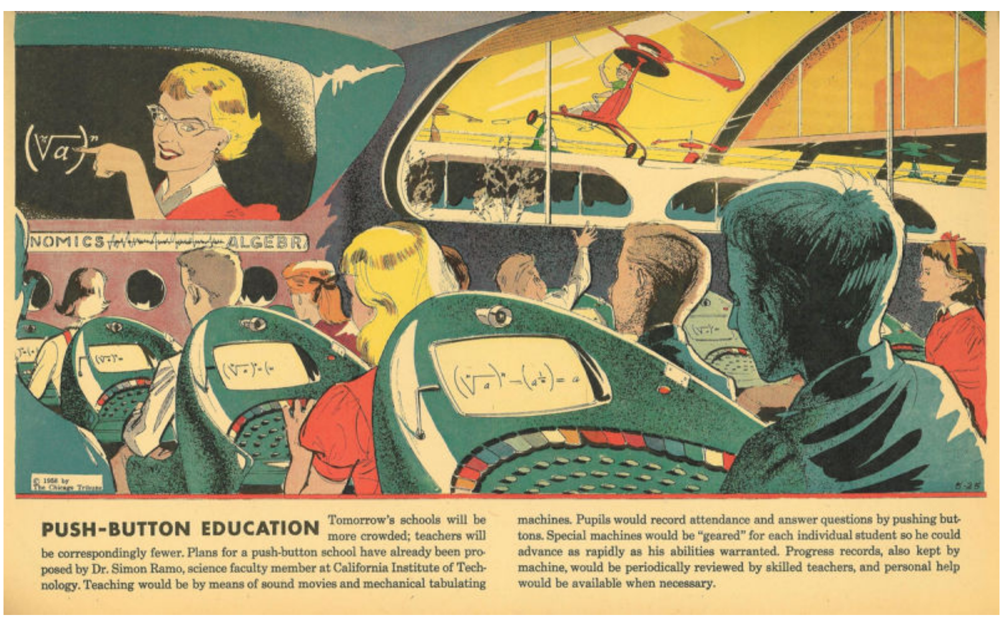


Figure 6.4. Illustration of the push-button school of tomorrow in the classic futuristic comic strip *Closer Than We Think* (May 25, 1958) (source: Paleofuture/Gizmodo)

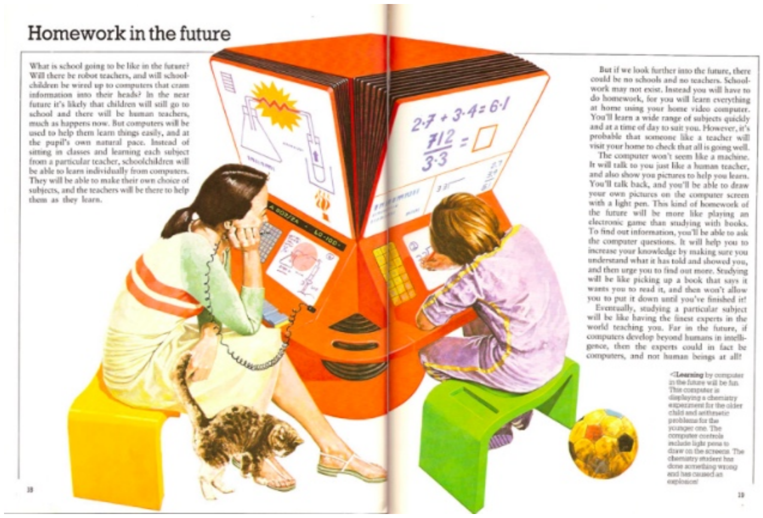
For example, “push-button education” was the topic of the May 5, 1958 edition of the Sunday comic strip, *Closer Than We Think*. The strip features pupils sitting in front of consoles, each one of which has a screen displaying equations, multiple colored buttons and what looks like a video camera or microphone mounted on the top-center of the desk. In the push-button school of tomorrow, textbooks would be replaced by “sound movies and mechanical tabulating machines.” Special machines would be “geared” for each individual pupil so that “[they] could advance as rapidly as [their] abilities warranted.”

Along those lines, Ardley predicted in 1981 that, with the help of intelligent machines, pupils would eventually be playing video games to learn, rather “than studying with books.” Ardley envisioned something akin to ‘enhanced’ MOOCs replacing schools, teachers and textbooks alike (p.54):[57]

> If we look further into the future, there could be no schools and no teachers. Schoolwork may not exist. Instead you will have to do homework, for you will learn everything at home using your home video computer. You’ll learn a wide range of subjects quickly and at a time of day to suit you. … The computer won’t seem like a machine. It will talk to you just like a human teacher, and also show you pictures to help you learn. You’ll talk back, and you’ll be able to draw your own pictures on the computer screen with a light pen. This kind of homework of the future will be more like playing an electronic game

[57] Meanwhile, predictions around the imminent death of books extended beyond the world of education. By 1966, in a Life magazine profile, Marshall McLuhan lumped books with other antiques: “clotheslines, seams in stockings, books and jobs — all are obsolete.” (Price, 2012) In interviews through the 1960s, **he** described humans as moving out of a print culture, into one that is electronically based (Carr, 2007; McLuhan, 1960). *With the invention of hypertext* in 1965 and, later, the personal computer (in 1976), claims about the obsolescence of print and paper-based communication methods became even more prevalent. In *Toward Paperless Information Systems*, F. W. Lancaster (1978) suggested that by 2000 we would be living in a paperless society. Similar writings in the 1970s and 1980s forecasted the marginalization of print library collections (De Gennaro, 1982; Kemeny, 1972; Lancaster & Bradley, 1989; Licklider, 1982; Ochai, 1984). Later, in the early 1990s, it was assumed that literary hypertext would liberate us from the finite, sequential and closed format of books, eventually making them altogether obsolete. In his seminal essay, “The End of Books,” Coover (1992) argued that the superior and endlessly deep narrative space made possible by the hypertext would bring “true freedom from the tyranny of the line” – although, well in the 2010s, it is apparent that books have not disappeared and that hypertext has far from killed the codex as a cultural form.

than studying with books. …Eventually, studying a particular subject will be like having the finest experts in the world teaching you.


Homework in the future

What is school going to be like in the future? Will there be robot teachers, and will schoolchildren be wired up to computers that cram information into their heads? In the near future it's likely that children will still go to school and there will be human teachers, much as happens now. But computers will be used to help them learn things easily, and at the pupil's own natural pace. Instead of sitting in classes and learning each subject from a particular teacher, schoolchildren will be able to learn individually from computers. They will be able to make their own choice of subjects, and the teachers will be there to help them as they learn.

But if we look further into the future, there could be no schools and no teachers. Schoolwork may not exist. Instead you will have to do homework, for you will learn everything at home using your home video computer. You'll learn a wide range of subjects quickly and at a time of day to suit you. However, it's probable that someone like a teacher will visit your home to check that all is going well.

The computer won't seem like a machine. It will talk to you just like a human teacher, and also show you pictures to help you learn. You'll talk back, and you'll be able to draw your own pictures on the computer screen with a light pen. This kind of homework of the future will be more like playing an electronic game than studying with books. To find out information, you'll be able to ask the computer questions. It will help you to increase your knowledge by making sure you understand what it has told and showed you, and then urge you to find out more. Studying will be like picking up a book that says it wants you to read it, and then won't allow you to put it down until you've finished it!

Eventually, studying a particular subject will be like having the finest experts in the world teaching you. Far in the future, if computers develop beyond humans in intelligence, then the experts could in fact be computers, and not human beings at all!

◁**Learning** by computer in the future will be fun. This computer is displaying a chemistry experiment for the older child and arithmetic problems for the younger one. The computer controls include light pens to draw on the screens. The chemistry student has done something wrong and has caused an explosion!

Figure 6.5. Illustration from Neil Ardley's (1981) *School, Work and Play (World of Tomorrow)* (source: Paleofuture/ Gizmodo)

In the mid-1990s, publishers started offering digital content in the form of CDs in the backs of textbooks in order to make their print products more competitively attractive as personal computers became more widespread in classrooms. While the extra content was in a few cases dynamic (e.g., videos or games), more often they were simply paper ancillaries 'printed' to the screen: PostScript or WordPerfect files that were to be printed out by the instructor as needed. Around that time, some textbooks publishers also started experimenting with digital textbooks (also known as 'e-texts'), although their use did not become widespread until well into the 2000s (Acker, 2011). Then, by the late 1990s and early 2000s, schools began investing heavily in student computing programs at the urging of school boards and parent groups who saw them as the key to the 21st century classroom. These programs ranged from laptop 'carts' in classrooms—where students checked out laptops from time to time—to full 'one-to-one' computing initiatives, where each student received her or his own laptop for use around the clock. In 2001, for example, Henrico County, Virginia, and Apple introduced a massive one-to-one program for all middle school students across the county (Abell Foundation, 2008). Every student in every middle school was provided a personal laptop. Eventually, high schoolers were added. During the same period, IBM (later Lenovo) launched similar initiatives in higher education, providing large-scale programs at Wake Forest University in 1996 and at UNC Chapel Hill in 2001 (Gladding, 2016; Li & Newby, 2002; Smith et al., 1999). The belief at the time was laptops and handheld devices would eradicate textbooks in a matter of years (Richardson et al., 2013; Sincar, 2011). Yet, by the late 2000s, some schools had already started phasing out their 'one-to-one' computing programs, citing technical frustrations and lack of impact on student outcomes among the top reasons (Hu, 2007).

In the years that followed, as technology improved and as digital texts became more widespread, many continued to predict the imminent death of the print textbook (e.g., Claxton & Cooper, 2000; Gates, 2010; Levine, 2000; Lewin, 2009; Rapp, 2008; Smith & Blender, 2008; Wardrop, 2010; Young, 2010). Others, were more skeptical (e.g., Carr, 2013; Foderaro, 2010; Paron, 2011; Wynn, 2008). For example, in August 2009, The New York Times published an article titled "In a Digital Future, Textbooks Are History" (Lewin, 2009). A little over a year later, the same paper ran an article titled "In a Digital Age, Students Cling to Paper Books" (Foderaro, 2010). This type of back and forth has marked much of the media coverage on textbooks and print (and their future) over the past decade.

With the widespread introduction of tablets in schools, and the growing popularity of Cloud computing, futurists and computer proponents envisioned the arrival of a paperless classroom (e.g., Clay, 2016; Johnson, 2017; Koebel, 2017; Scherer, 2014; Xander Apps, 2015). In a nutshell, the paperless classroom is a classroom in which teachers and students use computers or tablets as an alternative to paper notebooks and textbooks to exchange information and assignments electronically both in and out of class (Shonfeld & Meishar-Tal, 2017). Much of the hype around the paperless classroom was fueled by technology companies – especially Google – which pushed their products into schools by fetishizing the 'immateriality' of the Internet. Google announced the cloud-based suite of productivity tools (incl. Gmail, Docs, Sheets, Slides and Drive) 'G Suite for Education,' then known as 'Google Apps for Education,' on October 10, 2006. Google Classroom, a web service developed by Google for schools that "aims to simplify creating, distributing and grading assignments in a paperless way" was launched in August 2014 (Kerr, 2014). According to Google, as of 2019 G Suite for Education has 80 million users worldwide and Google classroom has 40 million.

Like the paperless office (see next section), it is argued that the paperless classroom is better for the environment, easier to manage (e.g., more centralized, less paper 'flying around', easier carryover from semester to semester), 'seamless' (that is, today's students are already steeped in digital technology) and more dynamic (e.g., students can receive immediate feedback, interactions can be 'personalized' etc.) (e.g., Bayne, 2017; GoodNotes, 2017; Hults, 2015; Miller, 204; Shonfeld & Meishar-Tal, 2017). It also supposedly increases student accountability, and student engagement, interaction and collaboration (e.g., Ferguson, 2017; Kashtan et al., 2016; Samson, 2018; Teeter et al., 2007). "The paperless classroom has the potential to far exceed the possibilities of the traditional face-to-face classroom." (Snyder, 2016). "As technology takes over your classroom, it's also getting rid of the papers. The paperless classroom will become the new traditional classroom." (Renard, 2017). "Bulky textbooks will be replaced by flat screens. Worksheets will be stored in the cloud, not clunky Trapper Keepers. The Dewey decimal system will give way to Google" (Scherer, 2014). These sorts of predictions echo those we continue to see in the media about the promises of an impending ‘ed-tech revolution’ (e.g., Allain, 2014; Bozorgzadeh, 2016; Brady, 2012; Miller, 2017; Ralston, 2014; Tanz, 2015; Wallace, 2018).

Figure 6.6. In October 2014, TIME magazine published an article predicting the imminent arrival of the paperless classroom (source: Mark Mahaney/ TIME)

The ideas behind the paperless classroom (e.g., efficiency, cost-effectiveness, personalization, innovation) also dovetail nicely with the idea of open (as in ‘unbound’) and digital (as in ‘immaterial’) education. As a results the two concepts – openness and paperlessness – often accompany one another. Over summer 2014, Laura Gibbs, Professor of English at the University of Oklahoma, created what she calls a paperless “un-textbook” for her MLLL 3043 Mythology and Folklore course (Taylor, 2014):

> The UnTextbook is […] a set of open resources that have been organized into a “book” — it is a book in some sense, yes, but also not a book. For one thing, it is paperless. No one, not even me, would ever print it out. In fact, I did not print a single piece of paper in the process of creating it.

At the 2015 MassCUE and M.A.S.S. 2015 Annual Technology Conference, Kerry Gallagher, Assistant Principal for Teaching & Learning at St. John's Preparatory in Massachusetts, gave a presentation titled "No textbooks, tests or paper. Just engaged learners." In it, she argued:

> Although they've been around for a long time, OERs have gotten a big boost very recently. We are going to see more teachers moving away from traditional textbooks and e-texts because there will be so many more high-quality resources available to them online. There will be increased adoption of the paperless creative model as a result.

And, in 2016, Ulanda Forbess, Director of Distance Learning and Faculty Professional Development at North Lake College in Dallas published a guide ('Going textbook-less with Open Educational Resources'), where she suggested: "Once you decide to ditch your textbook, give some thought to pitching the paper, too."

But has openness eliminated the need for print and paper? And do classrooms that adopt open textbooks become paperless (fully, or partially) as a result? In section 6.4. ('The myth of the paperless classroom') I draw on classroom observations in two undergraduate mathematics courses in Southern California, as well as existing research on print and digital preferences of students to challenge the assumption that digital leads to a natural, seamless and organic displacement of paper and print. Instead, I show how pen and paper and the ability to 'manipulate' notation by hand remains central to the practice of 'doing' mathematics – even more so in resource poor environments, like the one my study was conducted in. In the next section, however, I take a detour to provide a brief overview of the 'myth of the paperless office,' which informs and illuminates my look into the 'paperless classroom.'

6.3. A review of the myth of the paperless office

Before the paperless classroom, there was the paperless office. Or was it? Sellen and Harper (2011) trace the expression 'paperless office' back to an article titled "The Office of the Future" published in Business Week in June 1975. The second section of the article, titled "The Paperless Office," predicted the widespread use of electronic documents that would largely replace print. In the article, former head of Xerox Corp's Palo Alto Research Center George E. Pake described how electronic methods of managing information would progressively reduce the amount of paper used in the working environment. Looking forward to the futuristic office of 1995, he wrote: "I'll be able to call up documents from my files on the screen, or by pressing a button." Pake imagined that in the office of the future there would be little need to print out documents, because they would always be conveniently available for view using any available computer terminal: "I can get my mail or any messages. I don't know how much hard copy I'll want in this world."

Starting in the early 1980s (the beginning of the personal computer) this 'paperless' research-and-development mantra would increasingly become a marketing buzzword aimed at creating a large target market for selling information technology (IT). Marketing departments actively promoted a vision of massive magnetic archiving systems, destined to replace the huge amounts of messy paper, effectively de-cluttering the desktop once and for all. It seemed only a matter of time before the fruition of the vision of a paperless society. Yet, in the past thirty years, the opposite effect has occurred; that is, computer usage has actually increased paper consumption.

Today's office workers handle high amounts of digital content, on a far greater scale than paper documents, but, for the most part, the paperless office still eludes us. In fact, not only has the paperless office not arrived, but the production and use of paper, both personal and work-related, have actually increased in volume. According to a 2012 article in The Economist, paper consumption since 1980 has increased by half! This is what York (2006) has described as the “Paperless Office Paradox,” which refers to the observation that “the development of substitutes for a natural resource is not always associated with a decline in consumption of that resource, and in fact may occasionally lead to an increase in the consumption of that resource” (p. 145). According to the EPA (2013), each office worker produces about two pounds of paper waste every day and the average office uses 10,000 sheets of copy paper each yea. Meanwhile, a Smithers Group market report estimates that there were 48.8 trillion A4 sheets printed in 2017.

In *The Myth of the Paperless Office*, Sellen and Harper deconstruct the myth of ‘paperlessness,’ stating that: “We have heard stories of paperless offices, but we have never seen one. (...) For example in one organization, managers banned the use of personal filing cabinets, only to find that people resorted to using their car or home offices to store their paper files.” (p.13) The authors point out that, even though they themselves work in advanced research centers, and have access to most of the available devices for managing information, they are still surrounded by paper. For them, “the computer is the canvas on which documents are created, [but] the top of the desk is the palette on which bits of paper are spread in preparation for the job of writing.” (p.1)

Their reasoning for the endurance and pervasiveness of paper, is that the medium paper has certain ‘affordances’ —defined as perceived and actual properties of objects suggesting activities people do and think they can do with them— that electronic resources either do not present, or do not quite match. For example, paper has very high-resolution, supports thousands of typefaces, can present both black-and-white and color illustrations, and its high contrast makes it very easy to read. In a, users of paper documents—whether books, reports or letters—get a great deal of paralinguistic information from them at first glance. The layout can indicate quality or esthetic features, the way the text is broken up can help show the complexity of a document, and the mere thickness of a book or report gives insight into its contents. The hypertext features of books—with tables of contents, notes and indexes—make them ideal for non-linear reading. While electronic documents can only be viewed on the limited screen space of most monitors, actual printed papers can be easily spread across a desk, allowing a person to quickly switch between documents and pull out important sections without navigating task bars or menu bars.

For important documents such as contracts, moreover, paper can be signed and have legal binding. Paper documents can be annotated and edited by hand, and passed on to other readers who can add their comments. Although new features in word processing software allows for a similar kind of collaboration and review of changes, the paper based process is still more intuitive for many people. “The paperless office is a myth not because people fail to achieve their goals,” the authors note, “but because they know too well that their goals cannot be achieved without paper” (Sellen & Harper, p. 212) This is not to say that paper is superior to the electronic environment, but, rather, that the two have different strengths and weaknesses (or, affordances and constraints)[58] and will therefore continue to comingle and co-exist for the foreseeable future. In the next section, I present findings from my fieldwork that echo Sellen & Harper’s (2011) findings and that extend their work into the context of the classroom.

[58] For a deeper dive into affordances theory, see for example Boyle & Cook (2004), Gibson (1977), Hartson (2003), Hutchby (2001) and/or Norman (1990).

6.4. The myth of the paperless classroom

In spring 2017, I conducted fieldwork at a public university in the greater Los Angeles area and, over the course of four months, observed students in two undergraduate mathematics courses using an open textbook. The campus in question caters to a predominantly Latinx/ first-generation/ low-income population and is part of the California State University (CSU) System, the largest four-year university system in the United States. The CSU system is comprised of 23 campuses located throughout the state of California.

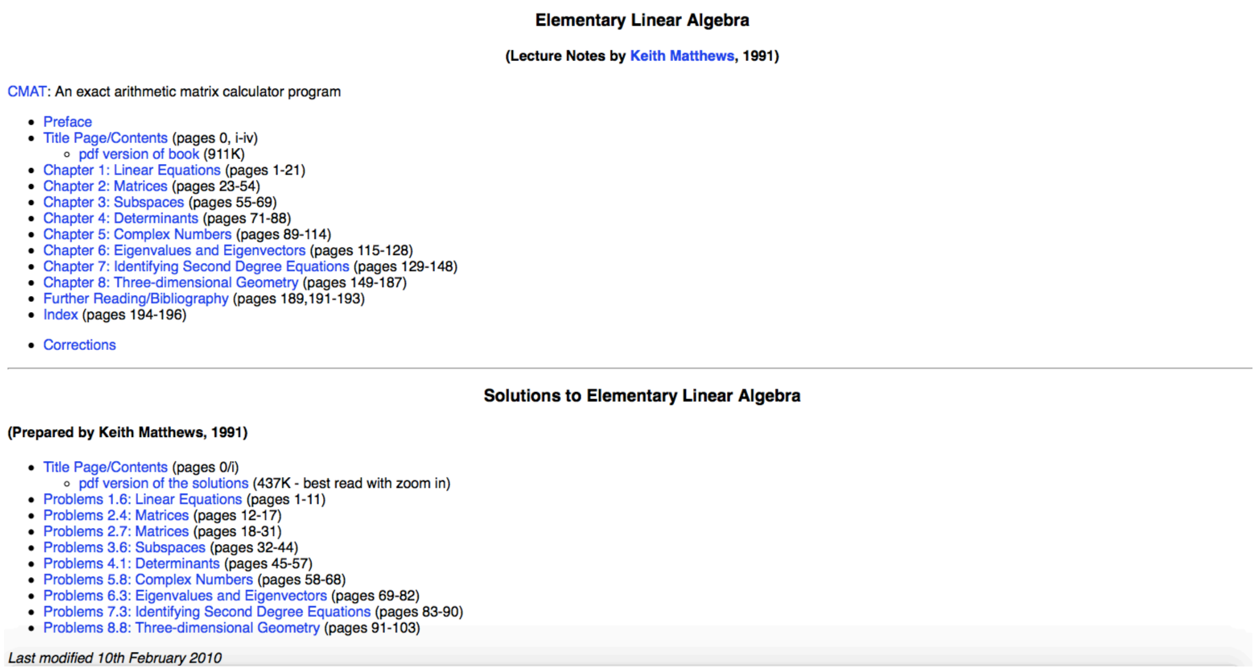
For nearly a decade, the California State University System has supported the adoption of OER primarily through a CSU-wide program known as Affordable Learning Solutions.[59] Affordable Learning Solutions (AL$) is funded by the CSU Chancellor's Office to support student savings through the adoption of low-cost and no-cost course materials, including but not limited to open textbooks. Other materials include, for example, ebooks owned by the library, digital textbooks, open courseware, publishers' repositories, textbook rental program and textbooks on reserve in the library. As of this writing, the majority of CSU campuses have an AL$ initiative, although the name, structure, size and scope of the initiative differs quite significantly among campuses. At some campuses, for instance, AL$ is strongly supported by local administration, involves many stakeholders (e.g., the library, the campus bookstore, the faculty technology center and the office for students with disabilities) and is a strong part of institutional branding. Yet at others, AL$ isn't as embedded into institutional processes, systems and culture, is more modest in size and centered mainly around the local library and its activities. Some typical AL$ activities across the board include providing faculty stipends for

[59] Other programs include MERLOT, an OER repository, and SkillsCommons, an online library of materials for job-driven workforce development.

implementing affordable learning materials (e.g., CSUN's Matador AL$ award), awareness and training workshops, and working with campus bookstores to negotiate prices with vendors.

At the time of fieldwork, only a handful of faculty at the campus I did my fieldwork at had adopted an open textbook, although many more were using a combination of library resources, their own notes and free digital materials. While the local AL$ initiative was nascent and humble in size, my conversations with instructors and staff at the school revealed that textbook affordability had been a concern for quite a while. Thus, many instructors had taken steps to reduce textbook costs in their classes before AL$ was even established. Others, were using open textbooks without necessarily being aware of the discourse around 'open,' thinking of these resources simply as digital texts their students could access for free.

The two undergraduate classes I observed were "Linear Algebra" and "Number Theory" and they were both taught by the same instructor. The text used in the algebra course was Keith Matthews' *Elementary Linear Algebra* (1991), which the instructor had been using for eleven years – that is, well before the AL$ program began.



Elementary Linear Algebra

(Lecture Notes by Keith Matthews, 1991)

CMAT: An exact arithmetic matrix calculator program

- Preface
- Title Page/Contents (pages 0, i-iv)
  - pdf version of book (911K)
- Chapter 1: Linear Equations (pages 1-21)
- Chapter 2: Matrices (pages 23-54)
- Chapter 3: Subspaces (pages 55-69)
- Chapter 4: Determinants (pages 71-88)
- Chapter 5: Complex Numbers (pages 89-114)
- Chapter 6: Eigenvalues and Eigenvectors (pages 115-128)
- Chapter 7: Identifying Second Degree Equations (pages 129-148)
- Chapter 8: Three-dimensional Geometry (pages 149-187)
- Further Reading/Bibliography (pages 189,191-193)
- Index (pages 194-196)

- Corrections

Solutions to Elementary Linear Algebra

(Prepared by Keith Matthews, 1991)

- Title Page/Contents (pages 0/i)
  - pdf version of the solutions (437K - best read with zoom in)
- Problems 1.6: Linear Equations (pages 1-11)
- Problems 2.4: Matrices (pages 12-17)
- Problems 2.7: Matrices (pages 18-31)
- Problems 3.6: Subspaces (pages 32-44)
- Problems 4.1: Determinants (pages 45-57)
- Problems 5.8: Complex Numbers (pages 58-68)
- Problems 6.3: Eigenvalues and Eigenvectors (pages 69-82)
- Problems 7.3: Identifying Second Degree Equations (pages 83-90)
- Problems 8.8: Three-dimensional Geometry (pages 91-103)

Last modified 10th February 2010

Figure 6.7. Screenshot of the landing page for Keith Matthews' *Elementary Linear Algebra* textbook.

The text used in the number theory course was William Stein's *Elementary Number Theory: Primes, Congruences, and Secrets: A Computational Approach* (2007). It is important to note that this is not an open textbook in the strict definition of the term (i.e., it is not openly licensed). It is a textbook published by Springer and which the publisher has agreed to make available digitally for free. It can be found in PDF format on the author's website at: https://www.wstein.org/ent/ent.pdf and in HTML at: https://wstein.org/edu/2007/spring/ent/ent-html/ent-html.html. The cost of the print edition (hardcover) as of this writing is $59.99. I decided to include it in this study because the instructor who used it viewed and described it as an 'open textbook,' although in our conversations he acknowledged that it wasn't 100% so. When I asked him how he chose this particular text, and whether at any point he considered a more 'formally open' resource, he responded that he was, first and foremost, driven by the desire to find a textbook that was free for his students. He also highlighted the importance of being able (or not) to establish trust in the author and in the text:

> [When I'm choosing a textbook] I'm looking at the author first. If I don't know them I look them up... I look at the author's publications -- they don't have to have a lot of publications, even if they have two publications, I can tell what kind of person they are; I can see whether I can trust them. Because I'm not going to read the whole book the first time in detail, I don't have the time to do that. So I just want to know if I can trust the person. Even if the book is less than perfect, that's fine, as long as it's written by a quality person.

When I asked if he was aware of OpenStax or LibreTexts, two of the providers examined in this study, he responded that he hadn't heard of them.

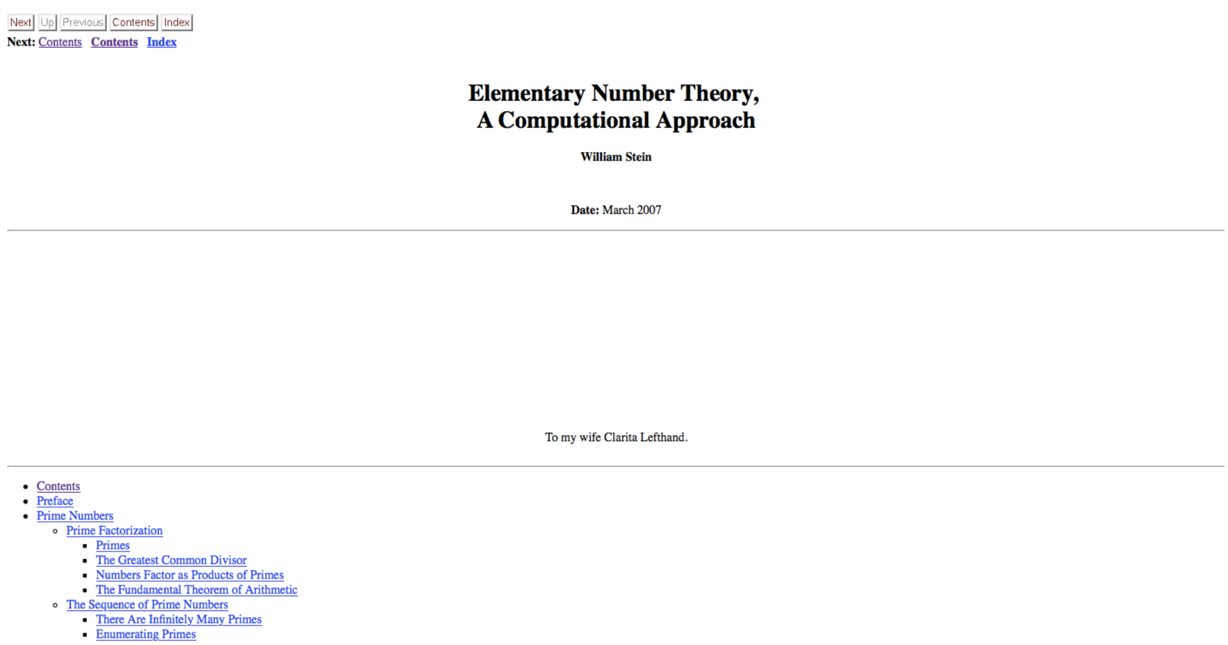


Figure 6.8. Screenshot of William Stein's *Elementary Number Theory*.

The use of a 'not-strictly-open-but-free-digital' textbook in this particular course, appears to reflect a broader trend in the OER/ textbook affordability community, where open textbook supply doesn't quite meet demand yet (Bliss, 2015; Seaman & Seaman, 2018; Seid-Karbasi et al., 2017) – especially in more specialized subjects, such as computational math (general education courses are generally better covered, in large part due to the work of OpenStax). In my interviews with instructors, about a third mentioned that they had to resort to using multiple resources to replace a traditional text. As well, most OER coordinators[60] acknowledged that quality open textbooks (and OER more broadly) were not equally available in different subjects.

Over four months, I visited the CSU campus in question three times a week. One of the things that struck me immediately, was just how much the classes (and classrooms) I 'joined' resembled the ones I myself attended in undergrad, over ten years ago. The chalk and blackboard, the fluorescent lighting, the desks and chairs lined up in perfect rows, paper everywhere. Below is an fieldwork diary entry from one of my second day in the Number Theory class:

It's 1:00 PM on a sunny afternoon in February. Classroom D301[61] *is located on the ground floor of the Social and Behavioral Sciences building on the south side of campus. It's a relatively small classroom that sits about 36 students. There is a brown blackboard that covers the south wall and blue-red plastic shell chair desks with fiberboard tops fill the room. The chairs have small storage rails underneath, but most students have placed their bags on the floor next to them. The desks are tiny and fit little more than a notebook, pen and water bottle.*

The desks are screwed to the floor and completely immobile, impeding any type of collaborative work. In their chairs and at their desks, the students' bodies are aligned in such a way that the direction of their gazes was prefigured towards the teacher and the blackboard. The instructor and his desk are positioned next to the blackboard, so that he can easily access it. Stacks of paper filled some desks, or peaked out of bursting backpacks. Their linear, almost military organization feels dated and reminds me of a high-school (or, primary, that is) classroom from the 1960s or 1970s -- not a contemporary college classroom. There is a classroom computer and a projector, but they are turned off.

The student on my right, a white woman in her early twenties, has the textbook chapter the class is currently working on printed out on her desk. It is printed in black and white and stapled. Next

[60] Depending on the institution, these were either librarians, or faculty who had been early OER adopters.
[61] The classroom number has been changed to protect confidentiality.

to it is a large, paper notebook, which she uses to copy what the professor is writing on the blackboard. There's also her cell phone, some flyers and a small colorful notebook that looks like a diary or an organizer of some sort.

At least five students have folders on their desk with pages and pages of hand-written notes and black and white copies of the textbook bursting out of them. The rest have simple paper notebooks. Nobody is using a laptop today.

Figure 6.9. Wednesday afternoon in 'Number Theory' (February, 2017)

The classes were taught in a 'definition-theorem-proof' format, a common way of teaching mathematics at the undergraduate level. Typically, the instructor stated formulas and proofs verbally and repeated them in writing on the blackboard. He thus spent a lot of time 'writing–talking' at the blackboard, i.e., writing things on the board while simultaneously saying them aloud – what is often referred to as chalk talk (e.g., Artemeva & Fox, 2011). Sooner or later all students copied the formulas onto their paper notebooks. The lectures were always well-organized, with plenty of in-classroom practice opportunities. The class also went over homework together, submitted weekly in paper format. But, nothing looked or felt like the high-tech, futuristic, collaborative, open and 'personalized' learning space envisioned by open and digital education advocates. This was in part due to the very materiality of the classroom, its layout, equipment and supplies, as noted earlier. It was also conditioned, in part, by the socioeconomic context of the school and its locatedness in a less affluent are of Los Angeles (i.e., no funding for iPads and/or interactive whiteboards etc.). Yet, perhaps more importantly, it was informed by the very materiality of doing math.[62]

It has been argued many times (e.g., Goody, 1977; Greifenhagen, 2014; Latour, 1986; Netz, 1999) that writing mathematics (on paper, blackboards etc.) is indispensable for doing and thinking mathematics. Latour (1986) has notably said that doing mathematics is like "thinking with eyes and hands" (p.1) – that is, thinking and writing in mathematics are inextricably interwoven. Meanwhile, Lave has explored in a number of studies how mathematical skills may be totally modified depending on whether or not you let people use paper and pencil (Lave, 1984, 1987 ; Lave et al., 1983).

So, why not just 'write' math using a keyboard? Traditional keyboards do not offer the affordances of 'manipulating' mathematical symbols in order to solve mathematical symbols and, while graphic tablets that imitate pen and paper have been available on the market for a while, they have not been able to infiltrate college classrooms. A number of studies have discussed the challenges of doing math using keyboard and mouse interfaces (e.g., Elliot &

[62] Surprisingly little work has been done of the years, investigating the materiality of mathematics (e.g., Greiffenhagen, 2000; Greiffenhagen & Sharrock, 2011; Pitsch, 2007; Warwick, 2003). Warwick's (2003) pedagogical history of the Mathematical Tripos at Cambridge University, for example, gives a brief account of how blackboards were gradually incorporated into teaching advanced mathematics. According to Warwick, until the early nineteenth century lectures were predominantly oral. Blackboards were slowly introduced as many students moved away from lectures and instead sought out coaches. While such coaches initially worked with only one or two pupils sitting together in front of a piece of paper, blackboards allowed them to talk to several pupils simultaneously. Along these lines, Greiffenhagen (2014) argues that the development of representational techniques are indispensable for doing and thinking mathematics, giving central place to the use of chalk and blackboard through an analysis of video recordings of graduate lectures in mathematical logic. It is worth noting that, much of the work that examines the material dimensions of doing math, is focused on chalk and blackboards as well as on how teachers use their bodies to visualize mathematical concepts, i.e., to help students 'see' math.

Bruckman, 2002; ElSheikh & Najdi, 2013; Romney, 2010; Ruthven & Hennessy, 2002), while a study by Anthony et al. (2008) shows that, on computer devices that allow handwritten input, extraneous cognitive load is reduced when using handwriting over keyboard input, and that handwritten and hand-drawn input provides better support for the two-dimensional spatial components of mathematics. Put simply, pen and paper remain the obvious choice for solving math.

When I asked the instructor about the use of paper in his classes and mathematics more broadly, he first seemed surprised and asked me: "So, how do you wanna do it?" When I explained, he simply stated: "Paper is cheap and everyone knows how it works." But, he also noted, some students preferred tablets, although (he acknowledged that) they weren't that common at his institution, because of "who [their] students are" (meaning first-generation, older students etc.). In the two courses I observed, only one student used digital 'pen and paper,' a black male in his mid-twenties with a penchant for gadgets and fashionable tech (he was also wearing an Apple watch and carried a golden pair wireless headphones). When I later approached the student and asked him about it, he said that he used his Microsoft Surface tablet "for everything." "Even to solve math?," I asked. Yes, he said, and showed me his stylus pen and some math he had just jotted down. He hadn't used a paper notebook in two years. "What about your homework," I asked, knowing that the instructor always requested hard copies. He usually does it electronically and prints it out, he said, although sometimes, if he's working last minute, he'll do it on paper.

Laptops rarely showed up in class, in part, I believe, because of the size of the desks that just wouldn't fit both the laptop and notebook students used to do math on and which made it awkward to try and work with both 'tools' at the same time. Occasionally, when the instructor used a projector to project the PDF of the textbook, some students would turn on their laptops in to see the text more clearly, as the writing on the PDF was small and hard to read from a distance. Below is another diary entry from the Number Theory class, later in the semester:

The instructor has a page from the textbook projected on a pull-down screen in front of the blackboard. It's section 4.3 "First Proof of Quadratic Reciprocity," which describes Grauss' Lemma theorem, a statement about polynomials over the integers, which the professor also writes on the blackboard and explains in his own words.

The text is small and hard to read from the back of the room where I'm sitting. One of the students in the middle of the classroom has the same page open on his laptop. He's not looking at it or interacting with it. He looks sleepy.

The instructor, meanwhile, points to Lemma's theorem and copies it with chalk on the black board behind him. He goes back and forth between the textbook on the screen and his writing on the board, gesturing wildly. He is trying to show students how to 'read' the book. Some students yawn, while others look confused..

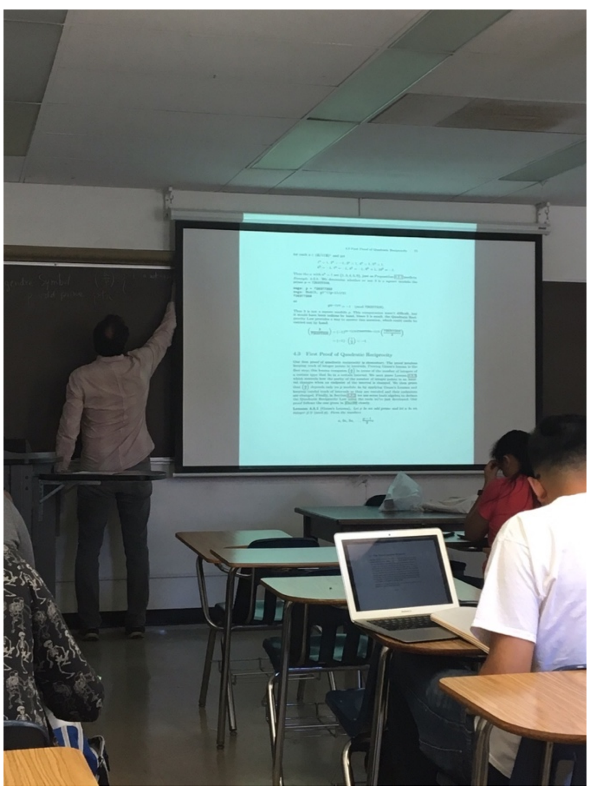


Figure 6.10. The instructor goes over Grauss' Lemma theorem, which he has projected on the screen and also copies with chalk on the blackboard behind him.

After a while, he goes back to his computer station, 'turns pages' electronically and moves on to "Euler's Proposition" (section 4.3.1).

Next Up Previous Contents Index
Next: Proof of Quadratic Reciprocity **Up:** First Proof of Quadratic **Previous:** First Proof of Quadratic **Contents** **Index**

Euler's Proposition

For rational numbers $a, b \in \mathbf{Q}$, let

$$(a, b) \cap \mathbf{Z} = \{x \in \mathbf{Z} : a \leq x \leq b\}$$

be the set of integers between a and b . The following lemma will help us to keep track of how many integers lie in certain intervals.

Lemma 4.3 *Let* $a, b \in \mathbf{Q}$. *Then for any integer* n ,

$$\#((a, b) \cap \mathbf{Z}) \equiv \#((a, b+2n) \cap \mathbf{Z}) \pmod 2$$

and

$$\#((a, b) \cap \mathbf{Z}) \equiv \#((a-2n, b) \cap \mathbf{Z}) \pmod 2,$$

provided that each interval involved in the congruence is nonempty.

Note that if one of the intervals is empty, then the statement may be false; e.g., if $(a, b) = (-1/2, 1/2)$ and $n = -1$ then $\#((a, b) \cap \mathbf{Z}) = 1$ but $\#(a, b-2) \cap \mathbf{Z} = 0$.

Proof. Let $\lceil x \rceil$ denotes the least integer $\geq x$. Since $n > 0$,

$$(a, b+2n) = (a, b) \cup [b, b+2n),$$

where the union is disjoint. There are $2n$ integers,

$$\lceil b \rceil, \lceil b \rceil + 1, \ldots, \lceil b \rceil + 2n - 1,$$

Figure 6.11. Screenshot of Euler's Proposition in Weiss's Number Theory text

Then he pauses and frowns. "You gotta be kidding me," he says abruptly. He points to an equation and asks a student in the class to check her print book and see if the equation looks the same. "No" she says, "it also has 'or equal' signs [in the print version]."

The instructor says it doesn't matter that the 'or equal' sign is missing online, and that it doesn't change the proof, but that "it doesn't look nice" and that he "considered asking him (referring to the author) to change it [in the online version]."

"That's the beauty of open textbooks," he says, "you can just make changes anytime. If you find mistakes in the book, you let me know and I will give you 5 extra points."

In four months of observations, this is the only explicit reference to openness that was ever made in class. When I later talked to the instructor, he explained that when his students find a mistake (or, more commonly, typo) in the online version of the book, he'll email the author to let them know. “Keith Matthews (the author of Linear Algebra),” he added, “has a list of corrections and who signaled the correction. So you have the names of everyone who’s found a mistake, he has the list of all my students and they see their names and they go ‘Ahhhhhh.’” Is there any other benefit to open textbooks, I asked him? He frowned again. Has he observed any changes in his teaching because of the textbook, I asked. Any new textbooks, he said, requires some reshuffling and restructuring, as they never cover exactly the same topics in exactly the same order. This isn’t unique to open or digital texts, he said.

Over time, I had noticed that he often brought a print copy of the Weiss text to class, although he regularly used the classroom computer to project the PDF on the board during his lectures. I noticed that whenever he wanted to look something up, he would reach for the print text, or grab a copy from one of his students. I asked him if it was important to him to have print as an option, even when a digital textbook is used. I also asked him whether he thought his students still valued print. He responded that while most students won’t buy the print book, a handful of them consistently do:

> I like having books in print, I don’t like to read on the computer and some of my students are the same. Julie[63], I don’t know if you’ve met her, she got [a print copy] and I asked her “why the hell did you buy it?” and she said “oh, I like the book”.

Later, I asked Julie about the print copy myself. “With digital books, it doesn’t feel like I’m actually reading a book. It doesn’t feel anything like it,” she said. Julie’s claim is backed by studies students’ print and digital preferences, as well my own conversations with other students in the two classes.

[63] Name altered to protect subject’s privacy.

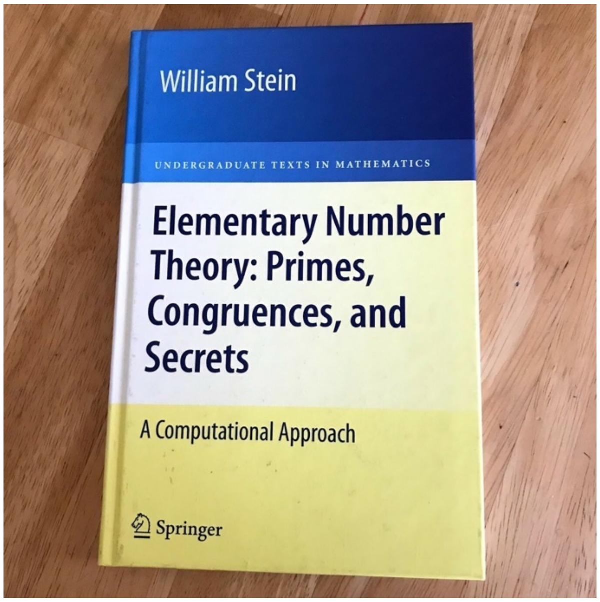


Figure 6:12. A student's copy of William Stein's *Elementary Number Theory*. Although the textbook is freely available as a PDF on the author's website, a few students had opted to purchase a hard copy of the text nonetheless.

Two of the students I formally interviewed,[64] and several students that I engaged in informal conversations with during fieldwork suggested, for instance, that while they appreciated the flexibility that open textbooks provide in terms of access 'anytime, anywhere' they still preferred print for 'deeper' or 'close' reading. The two primary reasons students offered for preferring print, were that they favored "how it feels," and that they thought it helped them learn better. A few students also mentioned that it is easier to "get lost" when reading online as you hyperlink from page to page, and that it can be hard to find your way back to your original point of departure. Because print texts are linear, it is easier to move from one location to another and back again.

[64] I should add that all of the students interviewed had previous experience with digital textbooks, so prior use did not appear to impact preference. Additional research with larger sample sizes is needed to better understand the contexts in which print is preferred. For instance, it would be interesting to explore how students' preferences defer by discipline, age, learning style, personality and socioeconomic background, to name a few. Future research will also need to look at different formats of open textbooks to understand how different features and affordances shape the student experience, as well as their preference or not for print.

These findings are echoed in research examining students' print and digital preferences. For instance, a 2016 study by the National Association of College Stores (NACS, 2016) found that 63% of students still prefer print. Interestingly, the majority of students who reported that they prefer digital said that the reason they choose digital over print, if given the option, isn't the features digital offers, but rather because it is generally less expensive than print (59%). Furthermore, students indicated that digital materials didn't seem to make a difference in their ability to learn the material. NACS's 2017-2018 report on students' attitudes and behaviors toward course materials, meanwhile, found that during the 2017-18 academic year, when purchasing course materials, 63 percent of students reported buying new print, 56 percent bought used print, and only percent bought digital (NACS, 2018).

Baron (2015) has also reported that students overwhelmingly prefer print when it comes to 'deeper' or long-form reading – however, the medium doesn't matter as much when it comes to 'light' reading. Among 400 students surveyed in her study, 92 percent said that they could concentrate best in hard copy. The choice of media included hard copy, cell phone, tablet, e-reader, and laptop. Students also reported that print is easier to navigate (e.g., it's easier to tell how far they are into a book and to remember where something is located),[65] and that finishing a print book gives them "a sense of accomplishment" in a way that electronic reading doesn't. Overall, students responses highlight the physical, emotional, tactile and kinesthetic components to reading. These findings are not surprising, given that print and digital texts have different affordances and may therefore be better suited for one type of reading over another (Drucker, 2013; Liu, 2005; Tanner, 2014). Several studies have found, for instance, that electronic media tend to be more

[65] A common counter-argument is that digital textbooks are easier to search than print texts. However, students may not remember the right term or combination of terms that will yield them the result they are looking for.

useful for searching, while paper-based media are preferred for actual consumption of information (e.g., Carr, 2011; Conole et al., 2008; Liu, 2005; Mangen et al., 2013; Marchionini, 1997).

Findings by McNeish (2012) et al. echo Baron's observations, as well. They investigated the use of paper textbooks among students who have used e-textbooks and digital resources but who have not given up paper-based content when they have the option to do so. They found students believe "that the paper textbook remains the superior technology for studying and achieving academic success" (p.61). Print's primary advantage is that it presents "fewer distractions" (p.61), the students said: "The paper textbook helps them to avoid the distractions of being on the computer or the Internet, the temptations associated with checking e-mail, Facebook, or surfing the Web for unrelated information" (p.61). A second benefit is that printed works encourage deeper study: "Students believe they learn more using the paper textbook versus the e- textbook in part because they are able to study longer with less physical and mental fatigue" (p.61). In addition, while aware of highlighting and sticky note features in e-textbooks, students felt that these processes could be more effectively performed with printed pages than digital ones. According to the researchers, "electronic sticky notes, in particular, do not provide the same memory assistance as the paper sticky note. Students feel that they have to remember to purposely search for the electronic sticky note, in contrast to the easily observable paper sticky note."

A number of other studies examining print vs digital preferences report similar findings (e.g., Enis, 2018; Foasberg, 2014; Jeong, 2012; McNeish et al., 2012; Precel et al., 2009; Rogers et al., 2011), although they suggest that the number of students who prefer print is closer to 60-65 percent (compared to Baron's 92 percent). Since Baron's study was conducted across the US, Japan, Germany and Slovakia, it is possible that local context, culture and availability/ quality of digital textbooks impact student perceptions. Baron's study also didn't include adaptive courseware, which is qualitatively different to a more 'static' (or less dynamic) HTML or PDF. In fact, most studied tend to 'lump' together multiple types of digital materials, which makes it hard to draw concrete conclusions in terms of what students like, why and in what context. For example, a 2017 study commissioned by McGraw Hill (Hanover Research, 2017) focusing on college students' "digital learning technology behaviors and preferences" reports that 55 percent of students prefer courses that use digital materials and 32 percent report that it makes no difference. In addition, 60 percent of students in the study reported that these technologies improved their grades and 65 percent reported that they help them learn and retain concepts better. Interestingly, students in STEM fields were "most likely," according to McGraw Hill, to report that technology improves their grades, although exact numbers aren't given in the report. This indicates that these tools may be more effective in some fields than others, which may in turn shape student preferences. The tremendous variance in terms of digital learning tools and platforms currently available on the market, however, makes it hard to interpret these findings. The McGraw Hill study did not just focus on McGraw Hill products, neither did it clearly operationalize 'digital learning technology.' Thus, students who have used tools with more advanced functionalities (e.g., adaptive courseware) may report higher grades or a preference for digital, but students using a standard electronic textbook (PDF, HTML etc.), may not.

Clearly, the landscape of educational content delivery is changing, but the transition from print to digital isn't quite as dramatic or glamorous as is often suggested by proponents of digital content. In the next and final section of this chapter, I share some observations from the field with regards to the role of print and how it has evolved within the open textbook over the past few years.

6.5. The end of print, or print without end?

When I visited the OpenStax headquarters in Houston, Texas, I was shown to a little glass office with designer chairs, a whiteboard and an expansive book display, where I waited to meet the team.

Figure 6.13. Book display at OpenStax's headquarters

Mary, the office manager, explained that this is where meetings with visitors usually took place. While I waited, I reflected on the prominence of the print textbooks on the shelf in front of me and wondered how they fit into the image OpenStax was trying to project. Here was a company that has been working on digitizing learning materials for almost a decade and whose founder had proclaimed textbooks dead more than once. How does this book display fit into this narrative, I wondered. And why isn't there also, say a tablet, that visitors can use to see the digital version(s) of the textbooks. Later, I asked senior developer Ross Reedstrom about them, who joked that they "look really pretty" and they're "a great conversation starter" in meetings. Meanwhile, managing director Daniel Williamson suggested that they're useful for communicating the work of OpenStax to visitors who may not be that familiar with the organization. "It's something that everyone understands," Williamson noted. A medium that "everyone understands." I thought it was a bold and insightful statement from a company that had tried so hard (see Chapter 5) to disrupt the textbook.

In the three years that I spent researching open textbooks, I found that the role of print and paper in OER was a prickly and contested subject. During interviews and at various open education events, I got into several almost-arguments at the mere suggestion that print and paper may still be relevant. I found that the most eager to discard print were publishers like MacMillan Learning – who have invested heavily in technology in recent years – as well as some open advocates and OER providers (with the notable exception of OpenStax). One provider even suggested they were "seriously concerned" about the "validity" of my research, given my interest in the "outdated" technology (paper, that is). This was at the same event that BCcampus Open Textbooks, a major open textbook publisher based out of the University of British Columbia, had used a prominent print book display to 'showcase' their work.[66]

[66] Note that the BCcampus Open Textbook project has been offering a 'print-on-demand' option for faculty and students since 2013.

Figure 6.14. BCcampus open textbook display at the Open Textbook Summit, Vancouver, May 24, 2017

These attitudes aren't surprising when considered within a media archaeology framework (Huhtamo, 1997; Huhtamo & Parikka, 2011; Parikka, 2013). For one, the digital utopianism that underpins much of educational technology asserts that the success of a new medium can generally be assessed by its power of disruption and displacement (Ballatore & Natale, 2016) – that is, a highly successful medium kills old media in a logic of supersession (Brown & Duguid, 1996; Gooding et al., 2013; Duguid, 1996). Secondly, the death of old media should not be mourned as a loss of cultural values and norms but should be embraced precisely as evidence of technological progress. Whoever clings to old media should be disposed of along with the medium – notably, Mitchell (1996) referred to bibliophiles as people "addicted to the look and feel of tree-flakes encased in dead cow" (p. 56). The underlying fear is that a medium that causes only a slight repositioning in the pedagogical landscape is not truly innovative. Thus, to legitimize open textbooks and digital learning tools more broadly, they must be discursively constructed as a willful and necessary ‘rupture’ from the past and its outdated processes/ technologies.

Print was the elephant in the room nobody wanted to talk about, especially in the beginning of my project. While it was acknowledged that print was still preferred by some instructors and students, they were often described in terms similar to how Mitchell (1995) described bibliophiles. It was hoped that, print along with its users, would soon enough be phased out. When I interviewed Delmar Larsen, founder of the LibreTexts project, in 2017, he wasn’t particularly eager to talk about print: “We can make PDFs in an ad hoc manner, we can print things out, we just don’t push it that way.” The platform was designed to prioritize online consumption, Larsen added. Yet, in March 2019, LibreTexts announced that it would start offering LibreTexts resources in print.

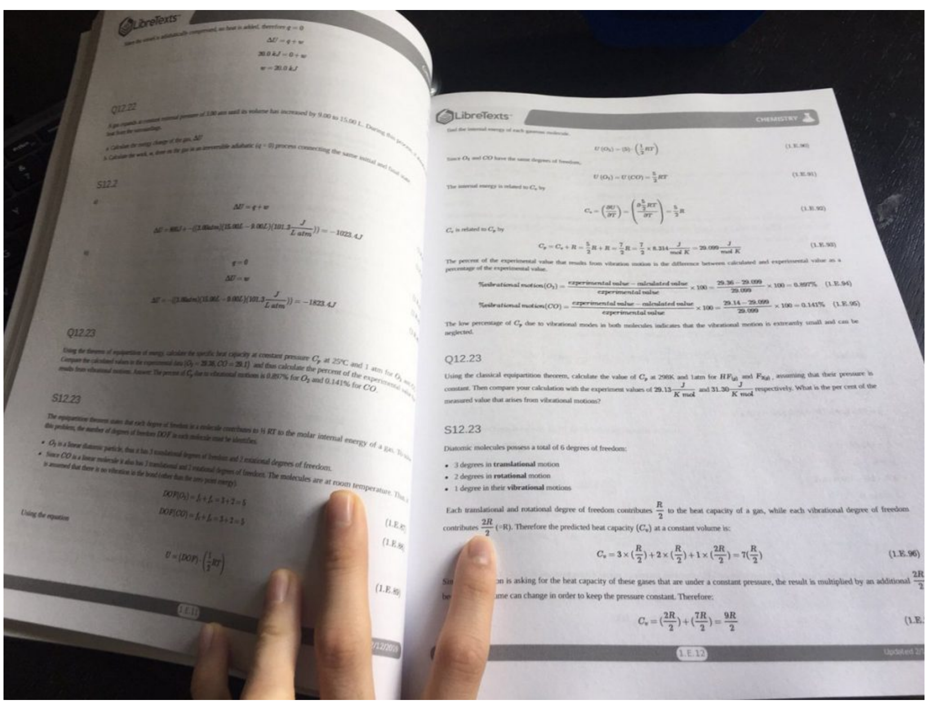


Figure 6:15 The first ever print copy of a LibreText (source: LibreTexts Blog)

This does not suggest a 'return' to print, per se. Educational technologies are evolving rapidly and adaptive learning systems are becoming more and more widespread (see next Chapter). More and more students are using digital learning tools and resources as a result. But digital hasn't eliminated the desire for print, a time-tested, tried and trusted medium that, perhaps, offers some comfort in an age of endless technological experimentation, hype and razzmatazz.

Figure 6:16 A LibreText display that includes both print texts (on the far left) and tablets (in the center) that the audience can use to interact with the digital version of the texts (source: LibreTexts Facebook page)

Even some major industry players are starting to acknowledge that, albeit reluctantly. For example, A.J. Goldman, vice president of textbooks and e-books at Chegg, a popular student services provider that notably sold its print textbook inventory to Ingram in 2015 and a partner to OpenStax, admitted in an interview with Ed Surge that adoption of digital materials among students has been slower than he predicted. "I'm done making predictions about" the death of print, Goldman said in the interview. “The industry has been proven wrong so many times. The market will only move as fast as students want to move.” (Millward, 2019).

6.7. Conclusion

New technology always threatens to supplant every single ‘old’ medium, while claiming to add new qualities, supposedly essential for the contemporary world (e.g., mobility, editability and searchability). And indeed, many ‘old’ media have been radically transformed from their previous forms and modalities by the internet – as we have seen happen with records, radio and television. At the same time, none of these media ever really disappeared; they ‘merely’ evolved and transformed, according to new technical and industrial requirements (e.g., Spotify, Netflix). The overblown tone in which the death of the textbook is being announced, should give us reason to pause and consider more closely the affordances of the currently emerging digital alternatives – and also how print, instead of disappearing, may instead adapt and evolve, as it has already done several times before.

This chapter has captured some of the complexity and dynamics of changing (and un-changing) materialities in higher education as evidenced through observations of classroom teaching practice, interviews with practitioners and teaching artifacts, in the classroom and beyond. In particular, my discussion has highlighted the durability of paper and paper practices within an increasingly digital environment, cutting through the so-called dichotomy between paper and electronics that dominates popular discourse, as well as much of the research in educational technology on ebooks, e-readers and digital courseware. Drawing on interviews and observations and theories of materiality, I have shown that open textbook practices are still in the process of being developed, experimented with, and re-shaped as print and digital technologies continue to comingle – much to the dismay of technology pundits and futurists who are eager to present new technologies as a dramatic rupture from the past.

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CHAPTER 7: CONCLUSION

7.1. Introduction

In this final chapter, I discuss the rise of adaptive learning software, situate it within broader trends in academic publishing and technology, and discuss some potential implications of this shift – that is, from content creation to software development and provision – for the OER movement. While this trend affects both the for- and non-profit textbook market, my discussion here focuses predominantly on OER providers (e.g., OpenStax). I have already touched on some of the issues surrounding the rise of adaptive learning platforms (also referred to as personalized learning platforms)[67] in Chapter 4, where I focused on for-profit platforms (e.g., McGraw Hill's "Open Learning Solutions," Wiley's "Orion" platform) 'absorbing' open textbook content and marketing themselves as OER providers. I discussed briefly the pedagogical assumptions embedded in these platforms and their impact on understandings of 'openness' and open education in the mainstream (i.e., outside the open community). Meanwhile, in Chapter 5, I discussed the evolution of OpenStax's business model from crowd-sourced platform, to traditional textbook publisher to learning software provider. Below, I extend this conversation by discussing more closely OpenStax's entry into the adaptive learning market, situate it within broader market shifts and reflect on what it means for the future of open textbooks. My discussion draws attention to the tensions between what is being promised for personalized learning and the practical realities, which are often obscured by the 'cult' of data that underpins

[67] To clarify, adaptive learning is only one way of proving personalized learning, which aims to provide efficient, effective, and customized learning paths to engage each student. The two terms, however, are often used interchangeably, especially in the media, in part because 'personalization' speaks to a broader audience.

personalized learning efforts. I also highlight how the appeal of the term ‘personalized learning’ can obscure the difficulty of accurately diagnosing a student’s misconceptions and offering appropriate remediation when a student gets a question wrong. I conclude this chapter by discussing the implications of my findings on theory and practice; outlining my contributions to the field of Information Studies and Education; and discuss future directions I my own research agenda.

7.2. From content to software services

In 2012, OER leader David Wiley wrote an essay titled “2017: RIP, OER?” (Wiley, 2017) In it, Wiley pondered whether the ‘death’ of OER was near. Wiley wrote:

> You have to admit that some of the things the publishers are working on are both cooler and better than almost everything that currently exists in the OER space. Can you name a single OER project that does assessment at all (and I don’t mean PDFs of quizzes)? Can you name one that does diagnostic assessment or handles mastery in any meaningful way? […]
>
> Open education currently has no response to the coming wave of diagnostic, adaptive products coming from the publishers. To the best of my knowledge there is no one really working on next gen OER – OER that are interactive, simulative, really rich with multimedia AND combined with OAR that drive diagnosis, remediation, and adaptation. There’s certainly no one funding next gen OER. And believe me – if it took $100M to get the field to where it currently stands in terms of relatively static openly licensed content, it will take at least that much investment again over the next decade for the field to do something truly next gen.

2012 was the year that Wiley co-founded Lumen Learning, a for-profit company that helps faculty create OER courses. Lumen provides a number of services,[68] including an adaptive courseware platform called Waymaker, which was launched in fall 2015 with funds from the Gates Foundation. Waymaker costs $25 per student per course and is designed as a textbook alternative – that is, there is no separate textbook but, instead, all content is divided into modules and integrated into the platform. Waymaker includes self-check questions and quizzes for students, customizable graded assignments and built in 'time-saving' messaging tools (e.g., email templates that instructors can customize and which the system automatically sends to students to encourage them if their performance improves).

OpenStax launched its own adaptive learning software, OpenStax Tutor, two years later. With Tutor, OpenStax is racing to compete with a market that is increasingly moving away from 'static' content to dynamic, interactive and 'personalized' learning experiences (Kolowich, 2013; Oremus, 2015; Straumshein, 2017). Priced at $10 per student per course, Tutor is one of the most affordable adaptive learning systems on the market. Rather than a textbook replacement, Tutor is designed as a 'companion' to the OpenStax texts and, much like Waymaker, includes reading materials, simulations, homework and assessments. "Essentially," Managing Director Daniel Williamson explained to me, Tutor "takes the content and makes it a smart textbook." In practice, that means that Tutor does what ultimately all adaptive learning systems do[69] (incl. those offered by other publishers): it breaks content into smaller 'chunks' and offers auto-corrected practice exercises for each module. As the system 'learns' about the student (by

[68] These include a catalog of already developed courses, which faculty can adopt without a charge. In order to create a new course within their Candela platform or to integrate with Learning Management Systems (e.g., Blackboard), Lumen charges $10 per student, which can be paid by the student or the institution.

[69] Although, I should note, the methods that these systems use for analyzing students' progress and providing feedback vary widely by product and discipline.

analyzing how they engage with both the text and the practice exercises therein), it generates a ‘personalized’ combination of questions based on an individual student’s performance and understanding of the course material. Students get ‘custom-tailored learning support’ and ‘instantaneous feedback’ (incl. performance forecasts), while instructors can access dashboards with student performance analytics and forecasting.

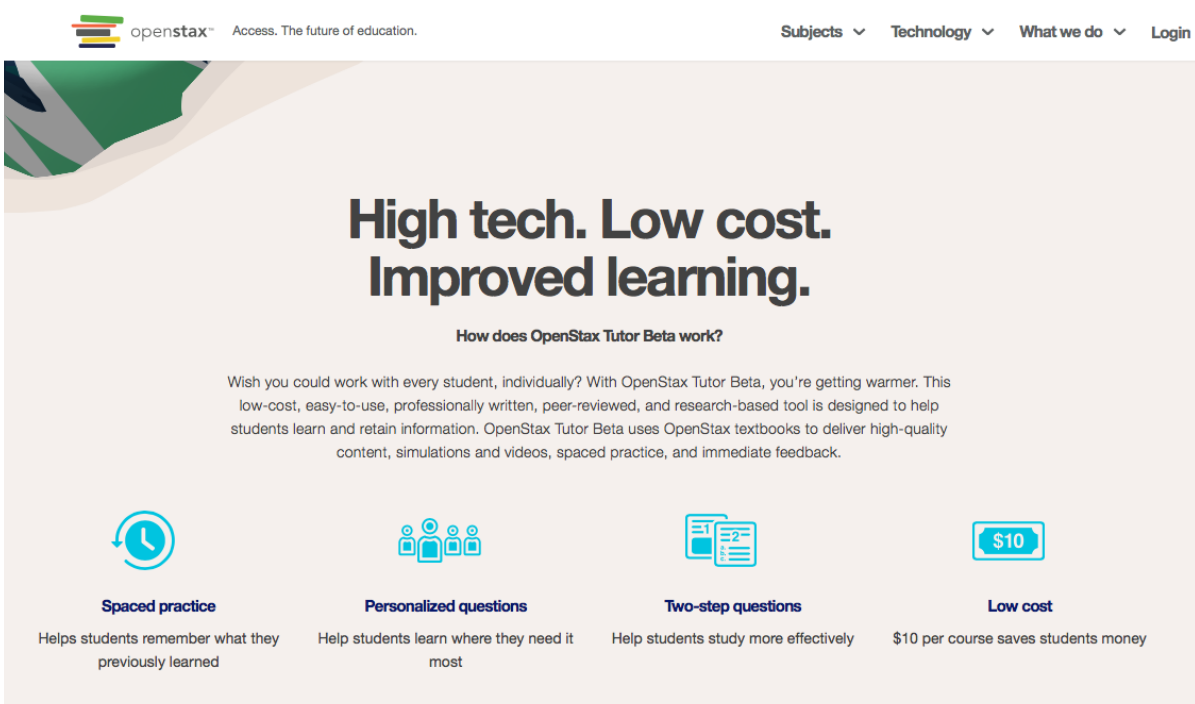

Figure 7.1.: OpenStax Tutor landing page

It is worth noting that none of these ideas are particularly new. In fact, the hope of using technology to reduce the burden of testing and scoring for teachers and therapeutically treat students after examination and diagnosis is at least half a century old. For example, Skinner, the behavioral psychologist credited with developing the first teaching machine, wrote in 1953:

> [Machines] are capital equipment to be used by teachers to save time and labor. In assigning certain mechanizable functions to machines, the teacher emerges in his proper role as an indispensable human being. He may teach more students than heretofore […] but he will do so in fewer hours and with fewer burdensome chores.

In a 1958, in an article in *Science*, he added (Skinner, 1958):

> The machine itself, of course, does not teach. It simply brings the student into contact with the person who composed the material it presents. It is a labor-saving device because it can bring one programmer into contact with an indefinite number of students. This may suggest mass production, but the effect upon each student is surprisingly like that of a *private tutor* [emphasis my own].
>
> Unlike lectures, textbooks, and the usual audio-visual aids, the machine induces sustained activity. The student is always alert and bury. Like a *good tutor* [emphasis my own], the machine insists that a given point be thoroughly understood, either frame by frame or set by set, before the student moves on. Lectures, textbooks, and their mechanized equivalents, on the other hand, proceed without making sure that the student understands and easily leave him behind.

These quotations highlight the longstanding hopes about technology 'helping' teachers in reaching, engaging, motivating and understanding more students. Like Skinner's 'teaching machine,' OpenStax Tutor's primary function is to 'reinforce' content. According to Director of Technical Project Management, Alana Lemay-Gibson, "Tutor is smart enough to learn over time that, 'hey, you're struggling with these concepts. Let's go back and reinforce those.'" "The textbook", she added, "can't do anything remotely like that." The idea, thus, is that the Tutor software will literally take on the role of tutor, helping students with routine skill coaching and practice so that the instructor is – in theory – freed up to give individual attention to those students who really need it. Moreover, since the instructor can observe the students' work in the digital dashboard (e.g., the time they took to complete specific tasks and the concepts they most struggle with), there is more opportunity to adapt instruction to focus on content students collectively struggle with. By offloading grading and tutoring, and by turning the students' study time into contact time (by making it observable to the teacher at a glance through analytics), the software acts – again, in theory – as an enabler of new teaching practices.

It is worth noting that as of this writing, instructors don't have the capability to edit the test questions students are prompted with, or to write their own prompts. They can only view the pool of available questions and exclude the ones that they don't want presented to students. While these issues are likely to be resolved in the future (Tutor is currently in Beta stage), what is unlikely to change is the fact that instructors using Tutor or any adaptive learning platform rely on predetermined pathways for content reinforcement and remediation. For example, when students get question wrong in Tutor, the system can direct them to a text, graphical, or video explanation that attempts to better explain the concept in question. But that requires the content authors to anticipate the common mistakes or misunderstandings that students may have.
This challenge is not unique to Tutor, but rather something all personalized learning software providers more or less struggle with–whether they admit it or not (Bulger, 2016; Oremus, 2015; Pane et al., 2017).

A related issue, is that of evaluating free-from responses and of the machine 'knowing' when a student is off-topic – an ongoing challenge for machine learning practitioners.[70] As of spring 2019, OpenStax was working on an algorithm "that can reliably detect when a student is off-topic." Until this is implemented in Tutor, OpenStax recommends that "instructors regularly review free-form responses and provide feedback to students." According to OpenStax, "often, simply the knowledge that someone (algorithm or human) is looking at the responses is sufficient

[70] See for example Farell & Rushby (2016) for an overview of the difficulty of analyzing natural language responses and the reliability of automated assessment of free-form responses.

to motivate students into providing better responses."[71] For now, OpenStax is relying mostly on multiple-choice questions, which, "based on research," OpenStax asserts, "is a very good format in terms of its psychometric properties and in terms of producing learning."

As of this writing, Tutor is available for OpenStax College Physics, Biology 2e and Introduction to Sociology, with more titles currently under development. Tutor is being developed with grants from the Bill & Melinda Gates Foundation, the Laura and John Arnold Foundation, and the Maxfield Foundation. This funding stream reflects a broader interest in 'personalized' technology solutions that has developed rapidly over the last decade (Achieving the Dream, 2019; Bulger, 2016; Cote, 2015; Herold, 2017; NPR, 2018; Oremus, 2015; Vignare, 2018). This interest is driven, in large part, by policy concerns that currently dominate the educational reform agenda (e.g., low degree completion rates, large education gaps between groups), as well as changing market conditions (e.g., textbook publishers shifting toward digital products as a way to address dwindling print sales).[72] Proponents, which include governments, policy makers and nonprofits, believe adaptive learning offers the best way to address America's "dropout crisis"[73] and to prepare students for college and career success. College presidents and

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[71] This unintentionally Foucauldian statement speaks both to the very pragmatic (and very obvious) limitations of current software, and to the more nebulous issue of black-boxed surveillance that is at the heart of personalized and data-driven learning. A deep dive into surveillance is beyond the scope of this dissertation but this statement needs to and will be unpacked in future work.

[72] See for example McKenzie (2018), Oremus (2015) and Straumsheim (2017).

[73] As of 2014, the U.S. college completion rate ranked well below average among 28 developed countries tracked by the Organization for Economic Co-operation and Development (Weston, 2014). Forty-five percent of all undergraduate students do not earn a degree within six years of matriculating into a college program. Meanwhile, at the community college level, nearly half of students (47%) drop out entirely (NCES, 2018). Importantly, broader social and economic inequalities are reflected in college attainment statistics. While high school graduates from the wealthiest families are almost certain to continue on to higher education, just over half of high school graduates in the poorest quarter of families attend college (Cahalan & Perna, 2015). Meanwhile, the expected college graduation rate for American youths living in the lowest economic quartile is approximately 9%, while that projection for the top quartile is 77% (ibid.). And while fifty-five percent of college students graduate within six years, the completion rate for low-income students is only around 25 percent (CFA, 2017).

provosts, meanwhile, are desperate to solve their degree-completion and other accountability metrics problems.[74] The vendors (both non- and for-profit) therefore market their products as a solution to degree completion. According to an EDUCAUSE report (Feldstein & Hill, 2016), "every textbook vendor and aspiring textbook disruptor knows that stories about improving pass rates through technology sell."

With adaptive learning platforms, new technology is promised –yet again– to level the playing field, effectively creating equal access to learning opportunities by democratizing instruction and learning. The belief that technology is always the solution, that all we need is more data and better analytics, remains very powerful. Broussard (2018) describes this tendency as 'techno-chauvinism'; Morozov (2013) calls it (technological) 'solutionism'; For Vaidhyanathan (2012) it is 'techno-fundamentalism.' Despite the differences in terminology, the core idea is the same: the optimistic belief that problems are best solved through technological solutions is naïve, problematic and perpetuates a disconnect between and what we think technology can do and what it is actually capable of achieving.

What exactly adaptive learning technologies are capable of remains unclear. One of the oldest and most influential adaptive software programs is Carnegie Learning's Cognitive Tutor for algebra, developed in the early 1990s at Carnegie Mellon University. Its efficacy has been closely studied over the years, and in some settings it has appeared to increase students' performance substantially (e.g., Anderson et al., 1995; Koedinger et al., 1997; Lovett et al., 2008). Others, however, have been unable to detect any impact of the software on student achievement (e.g., Cabalo et al., 2007). A 2010 federal review of the research also found "no discernible effects" on high school students' standardized test scores (Gabriel & Richtel, 2011).

[74] See for example Kreighbaum (2019), McGuire (2019), Muller (2018) and Warner (2018).

The picture was further complicated when the RAND Corporation published the results of a seven-year, $6 million controlled study involving 147 middle and high schools across seven states (Pane et al., 2013). The study compared students' performance in traditional algebra classrooms with those in "blended" classrooms designed around the Cognitive Tutor software. The results at the middle school level were inconclusive. At the high school level, the study found no significant results in the first year of the program's implementation. Students who took the software-based course for a second year, however, improved their scores twice as much between the beginning and end of the year as those who remained in traditional classrooms.

A study by Butler et al. (2014), which examined the impact of students using OpenStax Tutor Beta in an upper-level engineering class at Rice University, found that student exam scores (midterm and finals) improved by 7-9% when using the Tutor software. The Tutor intervention focused on three principles from cognitive science: repeated retrieval practice, spacing and feedback. While the research team described the findings as "impressive," the principles and relating practices described in the study are not inherently technology-dependent – that is, they can be implemented without the use of an adaptive software platform, albeit with a bit more work, perhaps, on the side of the instructor. In addition, while the study points out that students were much more likely to view their feedback under the Tutor intervention, it appears that this finding is influenced in part by the way the experiment was set up. In particular, students under the intervention were required to view the solution to each problem in order to receive credit for completing the assignment, whereas students under standard practice were not required to do so.

Overall, and with few exceptions (e.g., Lovett et al, 2008), studies report only modest improvements in student outcomes when adaptive/intelligent systems are used. Despotovic-Zrakic et al. (2012) found that students taking an adaptive learning version of a course did only moderately better on a business examination than did students who completed a non-adaptive version of the same course. Griff and Matter (2013) were unable to detect any appreciable differences in student achievement connected with their use of adaptive protocols. And, Murray and Perez (2105) concluded that adaptive learning has a negligible impact on student learning outcomes when outcomes are viewed as a component of learning quality (the researchers did conclude, however, that adaptive learning has a positive impact on other outcomes such as student persistence and engagement). In line with these findings, a 2014 meta-analysis of intelligent tutoring systems on college students' learning (Steenbergen-Hu & Copper, 2014) found that these systems have a "moderate positive effect" on learning outcomes (g = .32 to g = .37).[75] The researchers also found that intelligent tutoring systems were less effective than human tutoring, but that they outperformed all other instruction methods and learning activities, including traditional classroom instruction, reading printed text or computerized materials, computer-assisted instruction, laboratory or homework assignments, and no-treatment control.

Institutions, policy makers and philanthropic funders are nevertheless eager to invest in adaptive learning systems in order to help, in particular, 'underachievers' catch up. Since open textbooks are so much about increasing access and bridging educational gaps, it is no surprise that open textbook providers are reorienting themselves toward these technologies. Yet, as

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[75] Similar findings are reported by a 2014 study by SRI Education (Means et al. 2014), which was commissioned by the Bill & Melinda Gates Foundation, reviewed the major courseware-related projects in the foundation's Postsecondary Success portfolio. These included Carnegie Mellon's Community College Open learning Initiative (CC-OLI), a number of MOOC initiatives, OpenStax's Anatomy textbook (which isn't explicitly discussed in the report), and various partnerships between postsecondary institutions and adaptive learning technology vendors (17, to be exact). The purpose of the study was to draw implications for future investments. SRI reported that adaptive learning technologies demonstrated larger learning effects than non-adaptive ones, although, overall, effects on learning outcomes across the Postsecondary Success program were only moderate. They also found some projects (and related technologies) to produce much better results than others (e.g., Carnegie's Pathway project), concluding that "there is more to learn about how to design and implement digital courseware in ways that produce positive impacts consistently across different settings." (p.6)

suggested earlier, this shift is representative of where the entire industry is heading and where new dreams are born and old promises renewed about technology *finally* fixing, boosting and revamping US higher education.

For years, companies like Houghton Mifflin, Pearson and McGraw-Hill used their market dominance to protect multi-billion dollar textbook businesses. Now, they are moving more aggressively to embrace data-driven technologies, including adaptive learning. Houghton Mifflin bought Scholastic's tech unit, Knewton was recently acquired by Wiley, and Pearson has sold off the Financial Times and the Economist to focus more on education technology. Cengage is now calling itself a software company, while McGraw Hill describes itself as a "learning science" company:

> [O]ur adaptive courses harness the power of technology and the rigor of science to deliver better outcomes. Theories concerning focus, memory, metacognition, and engagement are embedded in the algorithms that power the personalized paths taken by every learner. (McGraw Hill, 2019)

When I started my research, I heard repeatedly that traditional textbook publishers were "dead" – that they would go out of business in a matter of years (and that open textbooks were going to be the reason). Instead, they have risen like a phoenix from the ashes,[76] dusted themselves off, and marched forward toward the elusive but compelling (and, seemingly, inevitable) future of computerized and data-driven learning. All publishers, meanwhile, are using terms like 'evidence-backed' and 'science-based' to justify this rebranding. The message: machines are better (i.e., more effective) than print textbooks ever were AND they are more affordable too. This is becoming a tough market for open textbooks that relied so heavily on the rhetoric of 'free' and 'affordable' to gain traction.

OpenStax has, once again, listened to the market and expanded its original mission of increasing access for students to 'advancing research on learning science,' as well:

[76] See for example Bond (2017) and Straumshein (2014).

> At OpenStax, our mission extends beyond increasing access to education. The OpenStax research team conducts cutting-edge research on student learning, leveraging cognitive science and machine learning to improve student success. With the support of philanthropic foundations, we are actively working to improve learning outcomes for students and advance the field of learning science. (https://openstax.org/research)

Arguably, this is a smart business move and reflective of where the whole industry is heading – at least for now. Yet, a lot remains aspirational at this point, and coated in the usual language of hype and hyperbole that marks pretty much all ed-tech. For example, OpenStax notes on their site that they are working on ways to "transform a neutral student strategy (highlighting and underlining) into something more [by] collecting student highlighting behaviors en masse to learn what the patterns indicate [and] make inferences about student knowledge states to adapt the learning process." At what point was highlighting ever a 'neutral' activity? And why is it assumed that patterns can provide insights that will, actually, *improve* learning? By studying patterns of behavior, iPhone predicts a range of apps that one might prefer using, Amazon predicts a range of products one might want to buy and Netflix predicts what TV show one might enjoy watching next. But are students consumers or are they learners? And, if they are both, how can we reconcile the two? These are questions that we need to keep asking as we move forward into an uncertain and rapidly changing education environment.

7.3. Looking ahead

So where does this leave us? We are in the midst of a phenomenon that is still taking shape, and that has, and will continue still, to provide fuel both for public conversations and academic ones. Education, learning and access are still clearly in the midst of an ongoing transformation, partly due to technological and institutional forces, partly due to larger socio-cultural and economic pressures. The ecosystem in which learners are to achieve access is evolving and becoming increasingly complex.

When I began my research, almost three years ago, OER was a grassroots effort with big ambitions for disrupting the education landscape. The non-profit network Achieving the Dream (ATD) had just launched an initiative (funded in part by the Hewlett Foundation and the Gates Foundation) aimed at helping spread the use of open educational resources to build OER degrees at community colleges (Smith, 2016). OER "are valuable for colleges and their students in terms of invigorating teaching and learning, lowering costs and laying the groundwork for degree programs that meet up-to-the-minute student and employer needs," said Karen Stout, president and chief executive officer of Achieving the Dream, in 2016. Three 'modest' goals: revitalize instructors' teaching and learning, reduce what students spend, and improve the relevance and value of the colleges' credentials. When ATD published a report assessing the impact of the initiative two years later, the network suggested that the program had saved students at least $1.4 million (Achieving the Dream, 2018). However, the report also stated that student awareness of the availability of the OER-driven courses remained low, that faculty overall resisted the work involved in creating such courses (mainly due to heavy time demands) and that ATD officials struggled to get some institutions and faculty to understand the value of creating fully openly licensed (as opposed to merely 'free') courses. The report concluded that making the OER degrees sustainable in the long run will be challenging without significant institutional support and investment (e.g., in technology maintenance, professional development and outreach).

Overall, while adoption of open textbooks and OER has grown over the years, it hasn't been at the rate open advocates had hoped. In January 2019, The Babson Survey Research Group released their latest report, “Freeing the Textbook: Educational Resources in U.S. Higher Education, 2018,” a survey of 4,100 faculty, which found that only 13% of faculty had used some type of OER in their classes the past year (although, the number is up from 6% in 2017). Among steps to reduce textbook costs, adoption of used textbooks and library or department copies were the most popular among respondents. The study also found that most institutions lack formal initiatives to promote OER among faculty members. As Tom Berger aptly observed in an article in Edutopia (2018), “OER have been on the cusp of arriving for more than 15 years, but somehow they never do.”

A major challenge that open textbooks and OER continue to face is that a vital aspect of the sharing economy—the idea that everyone is a content creator—is not panning out for OER. Adapting, remixing and resharing, as I have discussed, is also not happening at the rates the open education had envisioned. This is partly due to lack of user-friendly editing interfaces, but also – perhaps, more importantly – due to cultural and institutional issues, such as lack of time and lack of meaningful rewards for participation (e.g., course releases). Thus, creating better platforms and services to edit open textbooks and OER is unlikely in itself to lead to mass adoption. Ultimately, a key issue is that the OER community has not been able to clearly articulate the benefits of ‘openness’ beyond cost savings, especially in a way that engages (and convinces) faculty to adopt open practices. Conversations around ‘open pedagogy’ and ‘open educational practices’ are starting to take shape within the community, yet whether they will catch fire remains to be seen.

At the same time, the OER community celebrated a major ‘win’ last year, when the federal government put forward (for the first time ever) funds to support initiatives around open educational resources. In October 2018, the Department of Education awarded a sole grant of approximately $5 million to LibreTexts (backed by a broad national consortium of 12 institutions) to develop open textbooks focused on high-enrollment courses like chemistry, as well as career-technical education (CTE) fields. The language in the grant included a requirement that materials created under the pilot program be "licensed under a nonexclusive, irrevocable license to the public to exercise any of the rights under copyright conditioned only on the requirement that attribution be given as directed by the copyright owner." A second round of funding was approved by Congress in September 2018, including stricter licensing, and more explicit instructions that specify a minimum of 20 awards. The funding was met with hostility from the Association of American Publishers, who noted in an interview with Inside Higher Ed (Lieberman, 2018): "AAP believes that government should not distort the marketplace by subsidizing OER. […] We'll be encouraging the Department of Education to make sure that the materials created aren't duplicative of content that already exists." Ironically, many publishers have been using open content and 'locking it' inside proprietary systems and platforms, as discussed in Chapter 4. As well, as of 2018, every major US publisher (incl. Cengage, McGraw-Hill, MacMillan Learning and Wiley) except Pearson was a partner of OpenStax. In addition, as of this writing, all of them offer some type of OER-based product, from online homework systems, to OER search engines, to custom-textbook platforms (e.g., Cengage's Open Now, MacMillan's Intellus Open Courses, Pearson's Blue Sky).

But other models around affordability are emerging beyond OER that will ultimately test the durability of the open education dream. Most notable is the 'inclusive access' model that several major publishers have pivoted toward in efforts to regain control over the market, while also making the secondary resale market for print textbooks less appealing for students (Mckenzie, 2017). With inclusive access, instead of students purchasing textbooks on their own, the costs of course materials are automatically included in their tuition when they enroll. For example, Cengage has oriented much of its digital business around an annual subscription, called Cengage Unlimited, which gives students unlimited access to all of its digital textbook materials, along with online homework tools and study guides. This new model, according to the Cengage website, “saves money, ensures greater preparedness, streamlines processes and delivers results.” It is a model, Cengage adds, “that empowers faculty to teach without financial limits and equips learners with the resources they need to get all they can out of their courses.” A little ironic coming from one of the ‘big five,’ but nevertheless a powerful message that speaks to ongoing concerns in higher-ed around drops in college readiness, low degree completion, recurring budget cuts and mounting student debt.

Whether inclusive access persists as a model remains to be seen. A Nicole Allen, Director of Open Education at SPARC, has suggested, “textbook publishers have been through many iterations of models for proprietary digital content -- it is hard to know how long any one will last” (McKenzie, 2017). What is clear, however, is that publishers now offer viable and economic options that appeal to a growing number of institutions and individual faculty, and which directly compete with OER. Thus, if the open education community cannot come up with other, good reasons for using OER, the model might well be subsumed.

7.4. Implications of this study

This dissertation has captured the discourses, materialities and practices of open textbooks as they are unfolding in the state of California and asks what their emergence entails for teaching, learning, and the landscape of higher-ed more broadly. It established openness as a dynamic and ever-evolving phenomenon shaped, among other, by public discourses, market forces, technical infrastructures, institutional policies/priorities, personal values/ belief systems, and existing pedagogical practices and materials. My research has made the case that it is increasingly crucial to investigate empirically how educational technologies such as open textbooks 'come to be' (that is how they are constructed, both socially and materially-technologically), while at the same time assessing how these resources are *actually* deployed in practice. My findings indicate that binary conceptualizations of openness (i.e., 'open' vs 'closed') based on formal characteristics (e.g., licensing) are not reflective of how people 'do' openness in practice, and that diverging needs, values, priorities and interpretations of 'open' give rise to different artifacts and practices in different disciplines and institutional settings. Moreover, my study provides evidence for the need to separate open textbooks and openness from the notions of 'free of cost,' 'free of material constraints' and 'free of market forces,' which, I have demonstrated, they clearly are not. Importantly, my analysis has illustrated how the frictions of open textbook production, circulation, and maintenance – the labor and expense, cultural barriers, as well as infrastructural limitations – belie the fantasy of open textbooks as a dynamic interface prime for adaptation, modification and remix. Finally, in discussing the different models that OpenStax (formerly, Connexions) has adopted over the past 20 years in terms of creating and distributing content, this study has provided greater insight into the evolutionary paths of open textbooks given their technical and market structure.

7.5. Contributions to the fields of Science and Technology Studies (STS), Information Studies and Open Education

How can claims about open textbooks be effectively investigated? Simplistic, technologically determinist concerns with 'impact' mask the complexity of processes, infrastructures, materialities and interactions involved in the creation and use of open textbooks. This dissertation, instead, has proposed researching open textbooks as artifacts produced within a complex socio-technical apparatus that involves an ever-shifting assemblage of people, organizations, materials, ideas, practices, and infrastructural components. Drawing on the social construction of technology, emerging theories of materiality within STS and IS, and infrastructural approaches to the study of educational processes and artifacts, my analysis brings into view the infrastructural basis, the ideological underpinnings, the specific technological affordances/constraints, and the socio-material practices surrounding open textbooks.

Chapter 3 has traced the history of open textbooks and open education back to the Middle Ages, arguing against the common notion that digital technology – and particularly the web 2.0 – has been the primary driver of the open education movement. In addition, I have discussed some of challenges and shortcomings of earlier 'incarnations' of open education (e.g., MOOCs and Learning Objects) and underscored connections to current technical, pedagogical and economic issues that also mark the open textbook phenomenon. Finally, I have demonstrated that popular framings of open textbooks in the media and in policy discussions are part of a longer historical lineage of 'disruption' and technical 'fixes' that will, presumably, create a new culture of mass learning (but which time and time again fail to do so). Thus, I have made the case that open textbooks must be viewed and understood within not only a broader history of openness, but also a broader history of technology in the classroom.

Chapter 4 has captured the social construction of open textbooks. In this chapter I have examined how different stakeholder groups interpret 'open' and how their interpretations are shaping the ways that open textbooks are currently implemented in Californian higher education. Drawing on the SCOT framework, I have provided an avenue for understanding what openness means in practice, and how it can be better understood and researched. In discussing open textbooks, I have illustrated many of SCOT's main tenets, e.g. the various social interactions that surround and influence technology design and implementation. My analysis revealed notable differences in the interpretations of two primary groups – producers and users of open textbooks, as well as differences in implementation based on disciplinary and institutional context. In addition, my analysis has demonstrated that for-profit publishing and technology companies are attempting to define the OER space and its value faster than the educational community, and considered some potential implications of this trend for how openness is both understood and practiced.

Chapter 5 has used a case study of OpenStax to analyze open textbooks as computing objects that are distributed and interoperable within horizontal markets. It is one of the very few accounts of open textbook development that ground the topic within an organizational and market – rather than institutional, or classroom – context and that unmask the invisible labor of text formatting and markup, which is often overlooked in the open textbook literature, and which affects how and to what extent these resources are reused, remixed and redistributed. The description of this labor illustrates a major challenge of open textbook implementation in the way originally envisioned by open advocates – that is as modular objects that can be easily disassembled, reassembled and 'repaired' by instructors – and explains why the open textbook market has pivoted more toward readymade texts and courseware. It also supports my argument that open textbooks and their uses are grounded in the sociotechnical context of their production.

Chapter 6 has examined the convergence of paper and digital in the implementation and use of open textbooks in order to challenge popular claims that open textbooks will somehow liberate us from the 'mundane' and 'old-school' materiality of the printed text. In particular, my discussion has highlighted the durability of paper and paper practices within an increasingly digital environment, cutting through the so-called dichotomy between paper and electronics that dominates popular discourse, as well as much of the research in educational technology on ebooks, e-readers and digital courseware. My findings have also suggested that open textbooks tend to be used as 'mere' replacements for traditional texts, rather than as catalysts to introduce new pedagogies and assessment, which echoes previous studies on the pedagogical uses and impact of open textbooks. Finally, my findings provide empirical support for the argument that 'new' technologies do not automatically render 'old' ones obsolete, in particular when there is a mismatch between the affordances of the newer technology and the physical, cognitive and affective needs of the user.

All of my research draws from and contributes to STS, a field that examines the social, historical and cultural dimensions of the construction of knowledge, artifacts and practices. My research is also of relevance to Information Studies, a field that has long been concerned with issues surrounding the creation, management and use of electronic documents, and which more recently has produced a diverse body of work that seeks to challenge pervasive discourses on the presumed immateriality of digital information. Finally, my work contributes to ongoing research in the area of open education, in particular works that examine perceptions and practices surrounding open textbooks, barriers to implementation, and issues surrounding the design and sustainability of OER infrastructures.

7.6. Future Research

In this dissertation, I have argued that open textbooks are rooted in their socio-technical production processes. Here, I have focused on one such model, that of Openstax. Over the next couple of years, I want to expand on this work by looking at other models, as well, such as open textbook initiatives that are library-based and published (e.g., SUNY Open Textbooks, Humboldt State University Press), and projects that strongly involve students (e.g., College of the Canyons OER Textbooks, CUNY's Fashion History Timeline). I will also be collecting additional data on LibreTexts to see how their model has evolved since receiving the $5 million grant from the Department of Education (the interviews conducted in this study were performed pre-grant and a time the initiative was facing serious sustainability challenges). By bringing these different initiatives into a closer comparison, my goal is to investigate what might be 'opened' in different systems and processes, and what might be 'closed.' My intention, as well, is to draw more concrete conclusions about the sustainability of different types of structures, processes and practices.

Another question that has emerged from my research and which I look forward to studying further, concerns the pedagogic effects of different types of OER. This dissertation has demonstrated that there is an integral connection between the content of open textbooks, the systems within which they reside, and the material formats in which they are delivered. I believe that the structure of these relationships creates certain affordances, enabling certain practices to come into being, while constraining others. A better understanding of the affordances and constraints of specific systems and formats will, I believe, lead to better and more localized solutions. Such an understanding will also inform emerging discussions around 'open pedagogy,' which are attempting to reorient the attention of the OER community from (providing) access to thinking about what exactly students will be able to do once access has been granted.

Moreover, I will continue to investigate the consequences of the 'platformization' of learning, i.e. the increasing migration of educational content into digital platforms offering data-driven services such as adaptive learning and learning analytics, and its impact – especially – on how we 'do' education and how we think about teaching and learning. In particular, I will build on this dissertation by examining the ways in which the software that make adaptive learning technologies operate, assume and produce certain affordances and affects in their development and uptakes – that is, I will examine the work of code, algorithms and standards in curriculum-making practices in more detail. As data-driven technologies become more pervasive across the education sector and data-driven decision-making the accepted norm, it will also become increasingly important to train educators and administrators (both in K-12 and in higher-ed) in the critical interpretation of big data and learning analytics, and to make them aware of the inherent limitations and implications of such software. In the long run, I see my research moving into this direction, as well.

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APPENDIX I: LIST OF INSTITUTIONS INCLUDED IN THIS STUDY

List of institutions and organizations represented in this study:

	Institution/ Organization Name	**Type**	**Location**
1	Antelope Valley College	Community college	Southern California
2	Baruch College, City University of New York	State university	New York
3	Berkeley Community College	Community college	Northern California
4	Boise State University	State university	Idaho
5	Butte State College	State university	Northern California
6	California State University, Northridge	State university	Southern California
7	California State University, Dominguez Hills	State university	Southern California
8	College of the Canyons	Community college	Southern California
9	East Los Angeles College	Community college	Southern California
10	Foothill College	Community college	Northern California
11	Guttman Community College, City University of New York	Community college	New York
12	Humboldt State University	State university	Northern California
13	Lake Tahoe Community College	Community college	Northern California
14	Lane Community College	Community college	Oregon
15	Orange Coast College	Community college	Southern California
16	Pasadena City College	Community college	Southern California
17	Pepperdine University	Research university (private)	Southern California
18	Portland Community College	Community College	Oregon

19	Rice University/ OpenStax	Research university (private)/ Non-profit company	Texas
20	San Jose State University	State university	Northern California
21	SmartHistory	Non-profit organization	New York
22	University of California, Davis	Research university (public)	Northern California
23	University of California, Los Angeles	Research university (public)	Southern California
24	UCLA Extension	For-profit company	Southern California
25	University of Mary Washington	Liberal Arts College (public)	Virginia
26	West Hills College, Lemoore	Community College	Central California
27	West Los Angeles College	Community College	Southern California

APPENDIX II: INTERVIEW QUESTIONS

The categories of questions I asked in the interviews revolved around the following issues. Further questions followed up my informants' answers to my initial questions:

For open textbook authors:

- his/her perspective on the traditional textbook industry;
- their experience producing or using other OER prior to producing the open textbook (OT);
- why they decided to write their own OT;
- what were the main intellectual phases of the work?
- what are the skills and types of labor required to produce an OT?
- what the writing and publishing process looked like and who was involved in the different stages of production;
- if they have published a textbook with a traditional publisher before, how was the publishing process of the OT different;
- what publishing format and platform they chose and why? To what extend did accessibility concerns influence their decision if at all?
- support at the institutional and/or departmental level they might have received to produce the OT;
- how were they rewarded for writing the OT, if at all?
- barriers they encountered during production and distribution;
- who is using their OT in other departments/ institutions;
- are they updating the OT and how often?
- what is required institutionally, departmentally, individually and at the level of infrastructure for OTs to scale up?
- where do they see OTs in five years from now?

For instructors using open textbooks:

- what textbook(s) they were using before and why they decided to switch;
- resistance they might have encountered either at the institutional level or from their students;
- whether and how they use the OT in class;
- issues with regards to accessibility and how they are dealing with them;
- satisfaction with regards to how scientific notation is rendered;
- how they have modified the OT, if at all;
- his/ her perspective on the affordances and limitations of the particular OT and/or OTs in general;
- how the OT has impacted upon their teaching and instructional design; Do they follow a lesson plan set out by the OT? Has the OT changed their homework/ assignment practices? In what ways?
- what they think a good OT looks like;
- whether they plan to write their own OT and why/ why not;

- where do they see OTs in five years from now?

For students:

- what are the perceived benefits and limitations of using OTs;
- what does the user experience look like for them?
- how are they accessing the OT? Do they print it out or read it online? Can they access them from different devices?
- have they experienced any accessibility issues?
- how satisfied are they with regards to how scientific notation is rendered?
- do they participate in OT updates? What kind of labor do they perform?

For open textbook publishers:

- their perspective on the current state of textbook publishing;
- what the vision of their company/ organization is?
- how they would define an "open textbook";
- what do their OTs look like? What format do they use and why? What standards guide their creation? What actions are taken to ensure accessibility for all users?
- what the editorial process looks like;
- what the financial model of their company/ organization looks like;
- what types of data on users and usage are they collecting? Who has access to this data? What types of insights have they gained from this data so far?

For traditional publishers:

- their perspective on the current state of textbook publishing;
- how their company is adapting to changes brought forth by digital publishing;
- how they are engaging with open and affordable education;
- his/her perspective on the main affordances and limitations of digital textbooks;
- where is the textbook industry heading in the future?

For technology companies who develop open educational technologies:

- how is their company contributing to the open textbook arena? What products and service do they offer?
- if they have been involved in the OT environment for a while, how have industry priorities (and their products) changed over time?
- what are the largest challenges to accessibility from a technical and design perspective that they have encountered? How are they addressing them? What still needs to be done?
- what does their funding model look like? Do they receive support from the federal government, the state and/or private donors?
- his/her perspective on the largest challenges that OTs face overall;

For librarians:

- how involved are instructors at their given institutions in open access and open education efforts?

- what types of support is provided for instructors interested in producing and/or using OTs?
- how is their institution's open textbook/ textbook affordability initiative funded? Is there a long-term sustainability plan?
- to what an extend are open and affordable learning solutions an institutional priority?
- how accessible are OTs and OER more broadly? What services does the library provide for students with disabilities who are using OTs/OER in their courses?
- his/her perspective on the main barriers to widespread adoption of OTs;
- his/her perspective on the role of the library in open education;

For high-level administrators:

- what is their institution's attitude toward OTs and other affordable learning solutions?
- his/her role in open textbook/ OER implementation efforts;
- his/her past experiences with OER and lessons learned;
- his/her perspective on the sustainability of OTs;

APPENDIX III: THE TEXT IN THE MACHINE

1. Introduction

For the representation of texts in electronic form, markup is essential. Without it, a computer cannot display a text to a reader in a meaningful way. Markup languages are used to allow computer processing of documents. Several markup languages have been developed over the years, and although they have some similarities and, or may have the same origin, they are each designed to meet a different purpose. Overall, each markup language plays a particular key role in the organization and processing of electronic information. I start with a brief definition of markup and markup languages, and an overview of some of the most commonly used markup languages. I proceed with a brief outline of SGML (Standard Generalized Markup Language), which formed the basis of other markup languages. I then discuss the evolution and characteristics of HTML and XML, two languages that are central to the open textbook development process. I conclude by discussing the challenges of rendering mathematical symbols in digital environments, and provide an overview of existing methods for encoding mathematics, such as MathML.

2. Markup

Markup is the process of adding codes to a document to identify the structure of a document and to specify the format in which its fragments are to appear (Kohlase, 2006). The concept of marking up text is not new. It originates in the marking up of manuscripts, where handwritten markups were annotated in the form of printer instruction (Hunter, 2000). Until the computerization of the printing industry, markup was primarily done by a copy editor writing instructions on a manuscript for a typesetter to follow (Kohlase, 2006). These included instructions on the type of font to be used, the size to be used, whether bold or italics were to be used, to indicate underlining if it were necessary, to indicate spacing, hyphenation, indentation and so on. Every facet of the appearance of the printed work was represented in code to the typesetter (Gaskell, 1995).

In the digital environment, markup doesn’t target humans anymore. Rather, it tells software how to process data. Generally speaking, markup controls two complementary aspects of an electronic document: structure and presentation. Presentation refers to how the information looks (e.g. the color of the text used in the document, the font used in the headings and other such formatting issues), while structure refers to how the information is organized (e.g., the identification of some parts of text as headings, some parts as clauses, etc.) Early applications of the markup concept were PUB, developed at the Stanford Artificial Intelligence Laboratory in 1971, developed at Bell Laboratories for the then new Unix operating system in the early 1970s, and Scribe, developed at Carnegie Mellon in the late 1970s. These systems influenced each other and also developments such as LaTeX and SGML (discussed below).

2.1. Types of markup

There are two basic types of markup, presentational and semantic:

- **Presentational markup** is concerned with the visual presentation (rather than function) of a text. Depending upon what processing software is being used, the markup explains to the computer how the document should appear. For example, in a text file, the title of a document might be preceded by several newlines and/or spaces, thus suggesting leading spacing and centering. Presentational markup is concerned with structure only insofar as it relates to the visual aspect of the document. For instance, presentational markup is not concerned with whether a heading is for a book, a chapter or a paragraph — the only consideration is how that heading should look on the page. Presentation markup is widely used in text processors and desktop publishing systems (e.g., Microsoft Word), which aim to produce “ink-on-paper” or “pixel-on-screen” representations of documents. Another example of presentational markup would be HTML's <b> tag, which is used to indicate that a font should appear in bold.

- **Semantic (or structural) markup** describes the structure of a document in some way. It is used to categorize different parts of a text based on their role in organizing the document (e.g., sections and clauses, preambles and attachments, headings and bodies, etc.) Semantic markup does not tell the computer *what to do*, but rather what the text *is* (e.g., “**this section of the text is a paragraph.”)** The objective is to decouple the inherent structure of the document from any particular treatment or rendition of it. An example of semantic markup would be HTML's <cite> tag, which is used to label a citation.

There are two principle arguments for preferring semantic markup over presentational markup. The first is that semantic markup helps to make documents easier to understand for machine parsers, as for example search engine robots, agents, screen readers, accessibility software and the like. The second argument is that it is always a good idea to separate content from presentation, because it aids automation and it helps to simplify maintenance. In practice, the two types of markup are not mutually exclusive and usually co-occur in any given system. For example, HTML contains markup elements which are purely presentational (for example *b* for bold) and others which are purely semantic ("blockquote", or the "href=" attribute).

3. Common markup languages

3.1. GML and SGML

Computer encodings of documents have long concentrated on preserving the final form presentation, e.g. a nicely laid out paper document. Structured document formats take a different approach; rather than encoding the way in which the document will appear to the reader, they encode the logical structure and semantic content of the document. Among the reasons for doing so is the preservation of device independence, document searchability and information re-use in general.

The Generalized Markup Language (GML) pioneered the concept of structured documents. GML was developed in 1969 by IBM's Charles Goldfarb[77], Edward Mosher, and Raymond Lorie in order to help organize the vast amount of documentation the company had started to produce. It was a means of allowing editing and formatting of documents, as well as information retrieval on collections of documents. GML was used in an IBM system called the Document Composition Facility. The Standard Generalized Markup Language (SGML) is based on GML and was developed by a committee chaired by Goldfarb in 1974. By focusing attention on the structure of a document, SGML popularized a new approach to document management,

[77] See Godfarb (1999) for a more in-depth history of SGML.

one that treated documents as databases, rather than artifacts whose sole function was to be displayed (Raymond et al., 1995).

SGML became an ISO[78] standard in 1986 (it is, in fact, the first standardized markup language) and was quickly adopted by the U.S. Department of Defense, the U.S. Internal Revenue Service and the Electronic Manuscript Project of the Association of American Publishers (AAP), which fostered the use of SGML to encode general-purpose documents such as books and journals. SGML is a descriptive language; most languages before SGML were prescriptive languages.

SGML allows users to define their own markup vocabularies, essentially allowing them to create their own markup language; it is thus often described as a "meta-language." SGML uses a DTD, or Document Type Definition, to outline the formal specifications for an SGML encoded document. The DTD specifies what tags may be used, and which tags may be used inside other tags. Users can thus define tags in their DTD to mark whatever aspects of the text are important or relevant for their purposes. Because of this flexibility, SGML is cumbersome to learn and the software built to process it is complex and generally expensive. SGML, moreover, cannot be displayed in a web browser. In the last few years, the work on structured documents has centered around simplifications of SGML. Below I discuss two of these efforts in more detail: HTML and XML.

[78] ISO is the world's largest developer and publisher of International Standards. It is a network of the national standards institutes of 164 countries. ISO's work program ranges from standards for traditional activities, such as agriculture and construction, through mechanical engineering, manufacturing and distribution, to transport, medical devices, the environment, safety, information and communication technologies, and to standards for good practices and for services.

3.2. HTML

HTML, or Hyper-Text Markup Language, is what creates the basic structure of the World Wide Web. HTML elements are delineated by tags, written using angle brackets. Tags such as <img /> and <input /> directly introduce content into the page. Other tags such as <p> surround and provide information about document text and may include other tags as sub-elements. Browsers do not display the HTML tags, but use them to interpret the content of the page.[79]

HTML was developed between 1989-1993 by Tim Berners-Lee, a then employee of the European particle physics lab CERN, and the widely acknowledged inventor of the web (e.g., Dertouzos, 1999; Halpin, 2004; Hoy, 2011; McPherson, 2009). He created HTML to allow researchers who were not specialized in SGML to publish and exchange scientific and other technical documents. HTML especially facilitated this exchange by incorporating the ability to link documents stored anywhere on the Internet using hyperlinks – thus the name *Hypertext* Markup Language.

The concrete syntax and architecture of HTML is derived from the "Simple Generalized Markup Language" SGML. Berners-Lee borrowed many of the key layout concepts and tags in HTML directly from SGML, including titles, paragraphs, headings, ordered lists, and many others. Compared to SGML, however, HTML was compact and efficient. In a 1991 document called "HTML Tags" Berners-Lee proposed fewer than two dozen elements that could be used for writing web pages. Yet, HTML has gone through several changes since its inception. While Berners-Lee's original designs (e.g., HTML, HTML2 and HTML3) were widely adopted and used throughout the industry, they were never officially codified as standards. The first true

[79] For a more in-depth description of HTML see for example Musciano & Kennedy (2002).

standard for HTML was published by the World Wide Web Consortium[80] (W3C) in 1998. The next standard, called HTML4, added many new features including style sheets, frames, embedded objects, complex forms, and page accessibility tools.

Newer standards, based on Extensible Markup Language (XML – see next section), were developed in 2000 and revised periodically over the last ten years, with the most popular one being HTML5[81] (others include XHTML and HTML+). When HTML 4 was released in 1998, the web was primarily a source for static documents and accessed exclusively by computers; concepts such as multimedia support and mobile devices hadn't reached the mainstream. In the past 10-15 years, however, the web has transformed creating news needs around interactivity, multimedia support and multi-platform connectivity (and compatibility) options. To address these and other issues, the W3C released a new version of the HTML standard in October 2014, called HTML5.[82]

3.3. XML

[80] The World Wide Web Consortium (W3C) along with the Internet Engineering Taskforce (IETF) are responsible for the standardization of the Internet. The early 1990s saw a number of competing web browsers being developed, and many of them expanded and extended the capabilities of Berners-Lee's initial HTML design. This led to problems, such as pages designed for one browser displayed poorly or not at all in other browsers. In response to this splintering of the initial HTML standard, Berners-Lee formed the World Wide Web Consortium (W3C) in 1994. The W3C's stated mission is ''to lead the World Wide Web to its full potential by developing protocols and guidelines that ensure the long-term growth of the Web.'' To achieve that mission, the W3C develops open standards for many web technologies, including HTML.

[81] The history of HTML is complex and fraught with conflict. A detailed overview of how HTML has evolved and why, is beyond the scope of this dissertation. For a brief discussion on the evolution of HTML and the conflicts surrounding its standardization see Hoy (2011), Ford (2014), Jackson (2016) and WHATWG (2019). For a longer history see Raggett et al. (1998).

[82] For a detailed overview of the HTML5 specification see Pilgrim (2010).

Although XML succeeds HTML in time, its design is also based on SGML, which – as I've discussed – predates HTML and the Web altogether. Essentially, XML is a simplified and reduced form of SGML. Like SGML, XML (Extensible Markup Language) is a meta markup language, which means that it allows users to create their own markup language that conforms to some logical rules (although, it does have stricter syntax rules than SGML). Unlike HTML, it is used for storing and transporting data, rather than displaying it. Hundreds of XML languages are in use today, including GML (Geography Markup Language), MathML, MusicML, and RSS (Really Simple Syndication). XML in its raw form does not display on the web, and must be transformed into HTML using XSLT (eXtensible Stylesheet Language Transformations).

XML was developed in 1998 by the World Wide Web Consortium (W3C), in a committee created and chaired by Jon Bosak, then an engineer at Sun Microsystems. The main purpose of XML was to develop a markup language to represent data that could be used and consumed regardless of platform. XML allows users to create any tags needed (hence "extensible") and then describing those tags and their permitted uses. Each XML file is saved in a standard text format, which makes it easy for software programs to parse or read the data. Therefore, XML is a common choice for exporting structured data and for sharing data between multiple programs.

XML adoption was helped because every XML document can be written in such a way that it is also an SGML document, and existing SGML users and software could switch to XML fairly easily. However, XML eliminated many of the more complex and human-oriented features of SGML to simplify implementation (while increasing markup size and reducing readability and editability). Other improvements rectified some SGML problems in international settings, and made it possible to parse and interpret document hierarchy even if no DTD (Document Type Definition)[83] is available (DeRose, 1997).

XML was designed primarily for semi-structured environments, such as documents and publications. XML-based formats have become the default for many office-productivity tools, including Microsoft Office (Office Open XML), OpenOffice.org and LibreOffice (OpenDocument), and Apple's iWork. Because of its flexibility and relative simplicity, XML has been adopted for uses beyond publishing. For example, XML has provided the base language for communication protocols such as XMPP and is now widely used for communicating data between applications.

4. Markup for mathematical knowledge

So far, I have given a quick overview of markup and described the basic features of three widely used markup languages. Below, I focus on the problem of marking up mathematical knowledge and mathematical documents for digital environments. I discuss the history and current norms for representing mathematical documents on the Web, analyze what is missing to mark-up mathematical knowledge, and discuss how that affects the reuse of open content (incl. open textbooks) that makes heavy use of mathematical formulae.

4.1. A little history: TeX and LaTeX

The problem of encoding mathematics for computer processing or electronic communication is much older than the Web (Spyropulos et al., 2004). The common practice among scientists

[83] A document that defines the tagging structure of an SGML or XML document.

before the Web was to write papers in some encoded form based on the ASCII character set, and e-mail them to each other.

In the 1970s Donald Knuth created the software-based language TeX, a standard language for author-generated mathematical typesetting. Knuth developed TeX because there had been a change in the printing system used for the volumes of his book *The Art of Computer Programming*, and he was extremely unhappy with the quality of the typesetting. He thus decided to create a system that would allow authors to produce high-quality mathematical books using a reasonably minimal amount of effort, and that would allow the books (or other documents) to look the same on all computers. Knuth also designed the Computer Modern family of typefaces and the METAFONT language for font description. The work initiated in 1977 was finished (the languages were 'frozen') in 1989. TEX and METAFONT are not evolving any more except for minor bug fixes (Beebe, 2004).

In TeX, the program code and documentation are intermixed and developed simultaneously. Instead of visually formatting the text (as one would do with an application such as Word), the writer enters the manuscript text intertwined with typesetting commands in a plain text file. Thus, one uses markup to define the general structure of a document (such as article, book, and letter), to stylize text throughout a document (such as bold and italics), and to add citations and cross-references. A 'TeX' program is then run to read the document with its markup commands, and produce an appropriately formatted output (e.g., PDF). It is important to note that TeX is not XML or SGML, and it is mainly concerned with document layout and formatting rather than document structure.

TeX allows for fine-tuned control over the layout, including kerning and placement of mathematical functions. With TeX, one can print a page in multiple columns, flow text around a graphic or chart, and import multiple fonts and typeset them in a vast array of sizes and positions. TEX thus gives one more control over positioning and sizing than any other document preparation system. TeX became very popular very quickly and is now the de facto standard in many fields that make heavy use of math, such as computer science, economics, engineering, linguistics, physics, statistics, and quantitative psychology.

However, the flexibility afforded by TeX comes with a price; the language is quite complicated. In 1985 the computer scientist and Turing Award winner Leslie Lamport create LaTeX, a document preparation system that allows the user to more easily and consistently employ the flexibility and precision of TeX. LaTeX is not the name of a particular editing program, but refers to the encoding or tagging conventions that are used in LaTeX documents. Using either a graphical user interface (GUI) editor or a simple text editor, authors write a LaTeX input file that contains text and commands for processing and formatting that text. The author then compiles the input file using the LaTeX program, which produces a device-independent file (DVI) that can be used to generate PDF or PostScript files. In short, TeX handles the layout side, while LaTeX handles the content side for document processing.

4.2. Encoding math for the web

Overall, TeX and LaTeX solved the problem of typesetting math for printing on paper. Generating better graphical representations, however, does not solve the complexities of publishing digital math content on the Web. Ideally, mathematical notation should be searchable, indexable, readable to the visually impaired, and, in some cases, even ‘manipulable’ or solvable (as is in the case in ‘interactive’ textbooks). However, most of the math equations one currently finds online are encoded as static bitmaps (digital drawings) of equation images in GIF, PNG, or JPEG formats[84]. These images can be seen with the human eye, but they are devoid of non-visual information that which facilitate automatic processing, searching and indexing, and reuse in other applications and contexts.

For instance, one cannot generally seamlessly ‘cut and paste’ mathematical expressions from a web page into, say, a computer algebra package. Importantly, images can be inaccessible for people using assistive technology, such as screen readers. Although alternate text descriptions (commonly in the form of ‘alt tags) can be added to these images, this approach has drawbacks because text does not always provide true comparable access to information found in mathematical notation. Additionally, images are not customizable by the end user (font size, contrast, etc.), which affects users with vision problems and learning disabilities that often rely on text customization to improve readability. Furthermore, image formats are plagued by other usability and aesthetic problems such as ease of alignment, sizing, and color conformity with the text.

In order to address some of the limitations inherent in image-based encoding methods, the Internet community has – for the past 15+ years – been working on an alternative markup language for encoding mathematics for the Web:[85] MathML[86].

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[84] This has to do with the fact that HTML largely lacks structural markup capabilities for mathematical notations and other special notations used in science.

[85] It is worth noting that academic and scientific publishers as well as software companies have been very active in efforts to define a math specification for the Web. Publishers have legacy data in TEX and/or SGML and their options for displaying such documents on the Web has always been rather limited. Software vendors, meanwhile, want to link their products (e.g., a homework system for algebra) with mathematics in Web pages (and increasingly with content found in open textbooks). Moreover, academic publishers and software companies are increasingly interfacing with each other as the first transform themselves into technology companies (focused, in particular, on adaptive learning). Thus, the need to distribute math content in various formats and across different delivery channels has increased dramatically in the past 10 – 15 years.

[86] While I recognize that there are other languages under development (such as OpenMath), they are more idiosyncratic and not as widely implemented as MathML; I therefore do not discuss them here.

4.2.1. MathML

The Mathematical Markup Language (MathML) is an XML application for describing mathematical notation and capturing both its structure and content. Because HTML was invented in a scientific laboratory, formulas in HTML were one of the earliest extensions proposed. Early experiments, such as HTML+ in 1993, led to the first version of MathML in 1998. MathML has been gaining support ever since, although it took until 2014 and the fifth version of HTML before math became a standard part of HTML (rather than an optional extra). MathML can now be used both on its own, or embedded in HTML.

MathML consists of a number of XML tags that can be used to mark up equations in terms of either their presentation (i.e., the formatted appearance of the equation when displayed) or their content (i.e., the semantics of the equation). Presentation MathML focuses on the display of the equation whereas Content MathML focuses on the meaning, and its elements represent the functions applied in a formula.

MathML is currently the standard of choice for the accessibility community because of its detailed description of mathematical expressions. MathML contains sufficient information and structure to provide support for both visual display and alternative access means such as synthetic speech and braille. Equations which are encoded in MathML will increase in size as users change font size to increase readability, unlike images. When using synthetic speech, MathML will allow the user to set different verbosity levels and can automatically adjust for the user's native language. For braille users, using MathML will allow for the choice of various braille math formats, depending upon braille translation software support. In 2015 the MathML Association was founded to support the adoption of the MathML standard.

4.2.2. Inconsistent MathML support in authoring tools, web browsers, e-readers and apps

Despite the fact that MathML is part of both the HTML5 and EPUB 3 specifications, it has faced trouble in receiving native support in many web browsers -- and by extension, most reading systems, which are based on web browser software. Gecko-based browsers (e.g., Firefox and Camino) have robust native support of MathML thanks to their open source communities. MathML support in WebKit-based browsers (e.g., Safari) has improved significantly in recent years, although bugs remain. Google removed all support for MathML from its Chromium-based browsers in 2013 claiming architectural security issues and low usage do not justify their engineering time (Shankland, 2013). Moreover, despite Microsoft's recent stance toward embracing open standards (Gartnebreg, 2018; Mackie, 2018) and the addition of limited support for MathML in Microsoft Office, Internet Explorer and Microsoft Edge (Internet Explorer's successor) do not support MathML natively.

While a number of plugins (or polyfills) exist to help render MathML in browsers without native support, they come with their own limitations. Broadly speaking, they offer better support for presentation MathML than content MathML, and can have a hard time rendering more complex notations. Thus, they are not always able to meet the standards of the education and publishing community. Moreover, use of conversion software often implies that MathML is rendered as an image, thus perpetuating the exact problems MathML was developed to solve. As well, this type of software is often slow (MathML support directly in the browser would make rendering much faster), which, depending on bandwidth, can affect usability.

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